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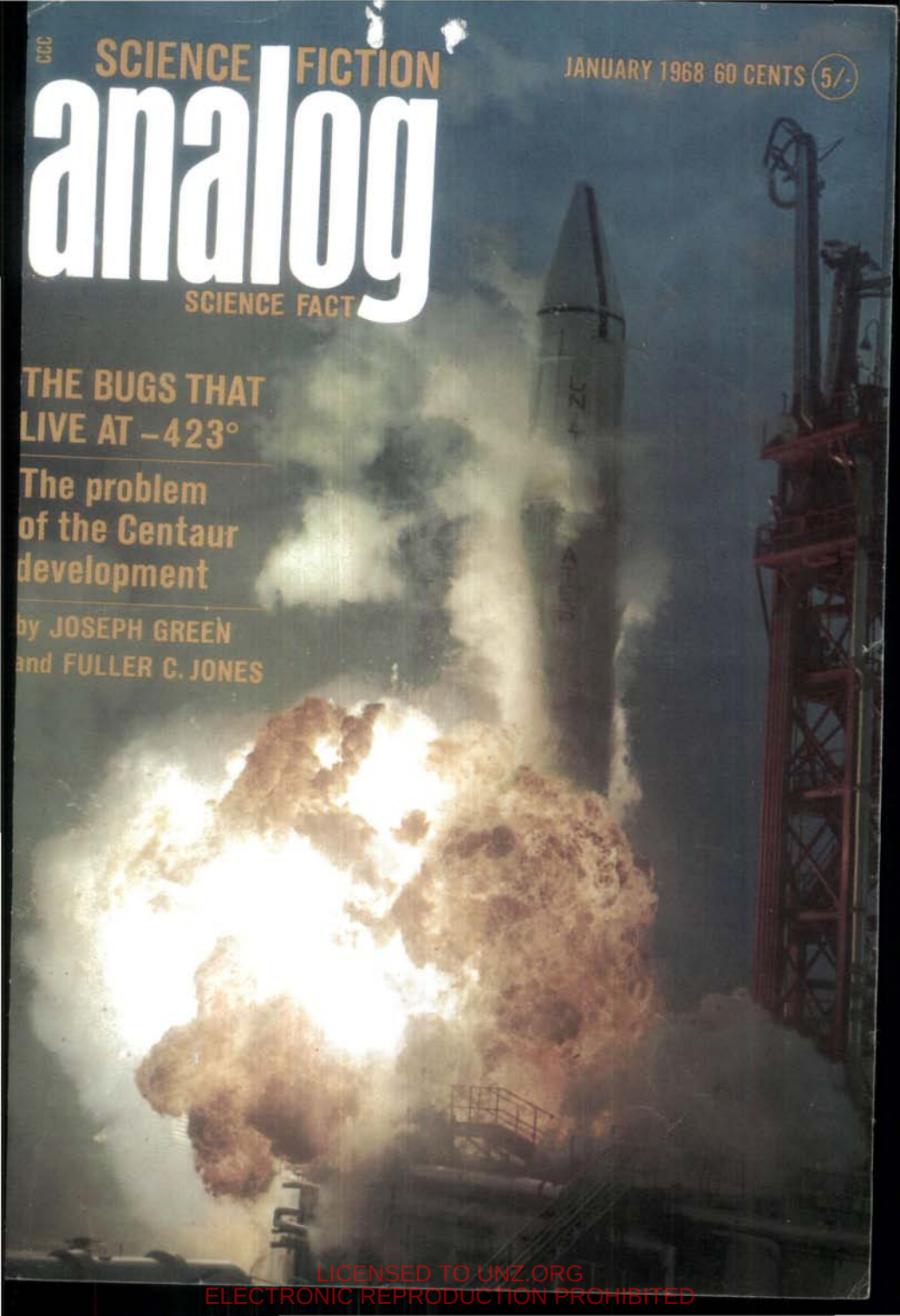

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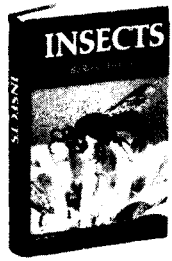

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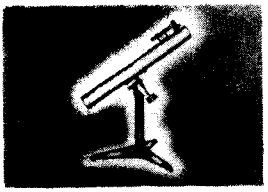

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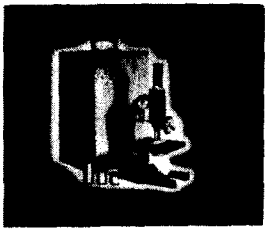

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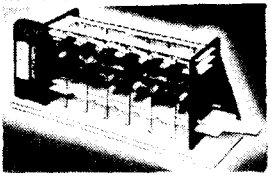

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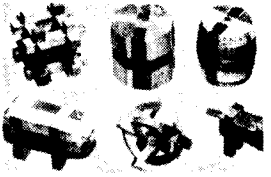

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An Editorial by John W. Campbell

Gadgeteer vs. Scientist

The essence of the gadgeteer is a driving urge to invent something—to find a way, or a mechanism, that will accomplish something he wants accomplished, or thinks people need to have accomplished. Not infrequently it is authoritatively known that what he's trying to do is impossible, but not understanding the argument that proves the impossibility, he keeps on trying anyway. And, not infrequently, succeeds in doing what all well-trained authorities know can't be done.

The essence of the scientist, in contrast, is to understand *why* things work. To him, the underlying factors that lead to the operation of the Universe are important—*all* important. Frequently great scientists are completely incompetent in a laboratory—like the fabled bride, they couldn't boil water without burning it. Many take pride in their tendency to cause any kind of apparatus they touch to collapse.

To such men, the only genuine, honest, real phenomena are *well-understood* phenomena.

The technician is halfway in between—and there is, of course, a spectrum of people ranging from the pure gadgeteer to the pure scientist.

The immense industrial success of this country, however, *was not due to scientists.* Scientists contributed practically zero point zero zero to the building of this nation's tremendous capital wealth—which is a demonstrable fact decidedly contrary to the propaganda currently taught in schools, magazines, newspapers, and TV ads. Something like 99.9% of all "Marvelous New SCIENTIFIC Breakthroughs" cited on TV ads no scientist would own to.

The advertising agencies have been legally compelled to take the trick white jackets off of their dulcet-voiced spielers who used to deliver their laxative ads, though white-coated gentlemen surrounded by anything from alembics to chromatograph plumbing are permitted in scouring powder ads.

Basically, the thing is based on the now-accepted status-symbol power that if it's *scientific* it's *good.* The common Aristotelian public reaction is then, not-scientific→ not good.

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That public concept is one quite naturally dear to the scientist type; he not only believes it himself, but gets continual reinforcement of its truth from those around him.

The facts are somewhat different, unfortunately.

First, be it recognized that Thomas A. Edison, usually cited as one of America's greatest inventors, was strictly, purely, a gadgeteer—definitely *not* a scientist. He found some use for hired scientist-technicians, but generally scientists kept getting in his way and causing him trouble. They kept proving that the idea which he was then working on was absolutely and completely impossible, thus making it exceedingly difficult for Edison to get the capital he needed to finish his research.

If modern income tax laws had existed then, Edison would have died a small-time telegraph operator: the graduated income tax would have stripped away the money he earned so that he'd never have built up the base capital to develop his laboratories. Setting up adequate research facilities is expensive: Edison was able to do it because the money he earned on early inventions remained in his hands, and allowed him to acquire the facilities needed to develop the next inventions

Sam Morse invented the telegraph: he was not a scientist; Joseph Henry was a truly great scientist, and had worked out and set up an electromagnetic telegraph system in his laboratories years before. But being a true scientist, Henry would not consider putting Holy Science to work for mere commercial interests.

Eli Whitney was no scientist; he figured out the basic mechanism of the cotton gin from watching a cat on a local railroad station working on some crated chickens. Neither the cat nor the chickens could get through the bars of the crates—but the cat's clawed paw could, and the chickens' feathers did. Presto! The gadgeteer saw how to remove the clinging fibers from the cotton seeds mechanically!

The McCormick Reaper—Elias Howe and the sewing machine—Henry Ford's Model T—gadgeteer after gadgeteer dominated the history of American industry. Alexander Bell was no scientist; he was a gadgeteer trying to invent one thing—a "musical telegraph"—who stumbled on something entirely different, and had gadgeteer-wits enough (like Whitney, reacting to the cat-and-chickens observation) to recognize a discovery when it became available.

The Wright brothers were Edisonian type gadgeteers, not scientists. (The true gadgeteer, remember, doesn't spurn science—except when it gets in his way by saying he simply *can't* do what he's damn well determined to accomplish.)

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The Bugs That Live at –423°

There's no triumph in getting water to run down hill—that's no challenge. But getting the impossibly misbehaving, viciously destructive, but enormously powerful liquid hydrogen to do what you want, instead of what it wants, was one of the greatest challenges—and achievements!—in modern science-technology.

JOSEPH GREEN / FULLER C. JONES

BACKGROUND

Our authors have underemphasized some of the simpler aspects of taming liquid hydrogen.

In the first place, the vapor form of hydrogen is excessively happy to form explosive mixtures with air. Leaking lox doesn't bother anybody—unless it spills on him, while still liquid. Jet fuel can be ignited, of course, but it takes a little effort. Fuming nitric acid is dangerous if it gets on you . . . but the vapors warn you before they bite. And the vapors don't form explosive mixtures with air.

Liquid hydrogen is cold. The language has no adequate term of course—it's the kind of cold that, on contact, turns high-strength steel more brittle than glass.

Liquid hydrogen—and near-liquid gaseous hydrogen—displays physical behavior that drives physicists to hair-tearing. Most gases, if expanded through a nozzle, undergo a drop in temperature. Not hydrogen! It warms up!

The AC-5 vehicle settling back on pad after booster engines cut off. The bottom of the vehicle is already crumbling and the fireball forming. Two seconds later the vehicle was completely hidden in a massive cloud of fire.

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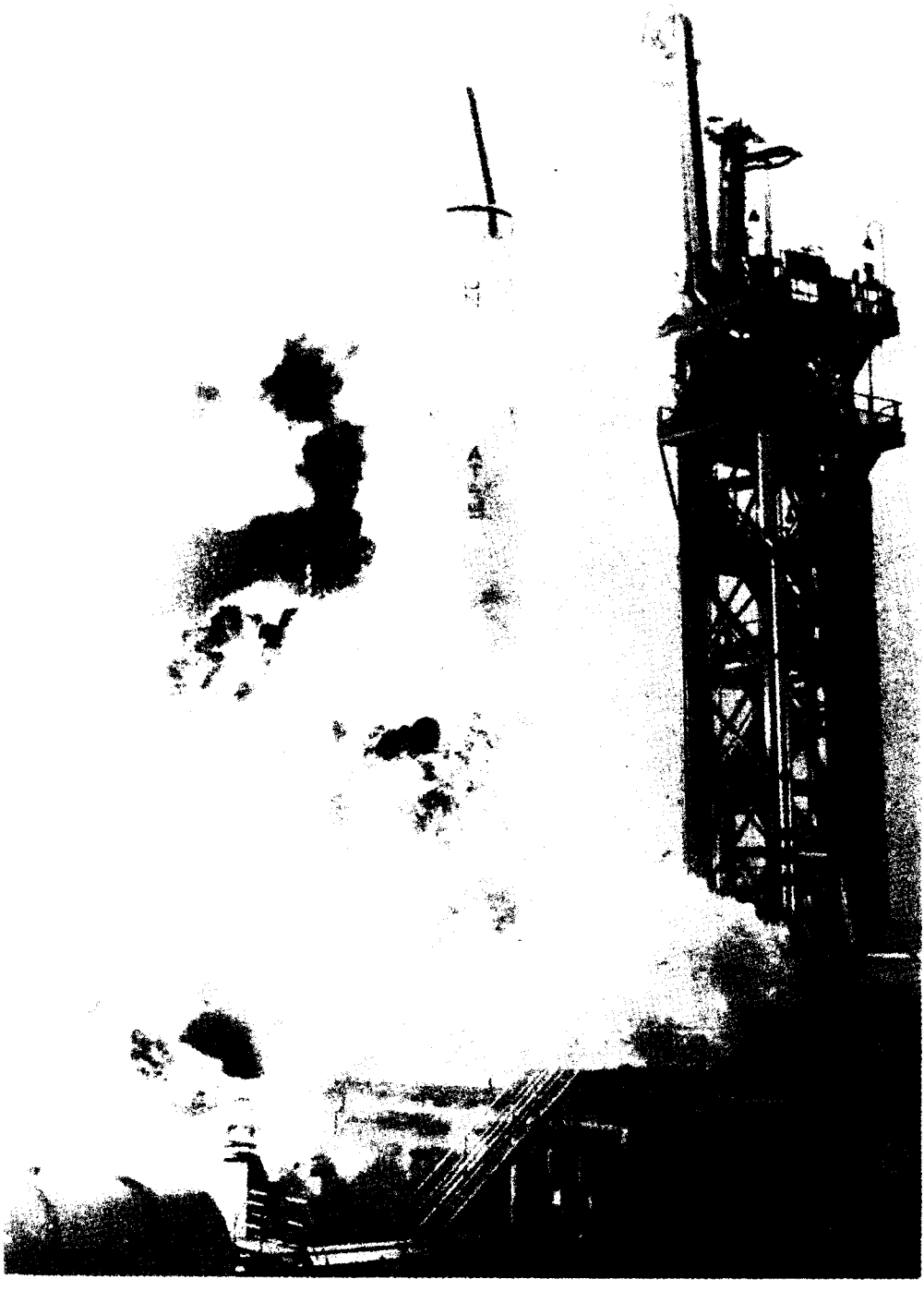

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Its behavior is weird; it leaks rapidly through airtight joints. That the stuff presents extremely tricky problems, even in highly sophisticated laboratory work, is perhaps best demonstrated by the explosion of the liquid hydrogen bubble chamber at the Cambridge Electron Accelerator laboratory a year or so ago.

High pressure hydrogen reaction vessels blow up so frequently, that engineering practice now routinely surrounds them with explosion-stopping barriers. Hydrogen can leak into solid steel, react with the metallic crystals, and embrittle the metal beyond use.

Taming hydrogen for use as a rocket fuel was one of the true technical-science accomplishments of the whole space program.

And it has been done so magnificently that the Centaur rockets now achieve a record of near-perfect accuracy in placing their packages on precisely the selected spots on the Moon—or in precisely the desired orbits around the Moon.

And their power is so great they are capable of lofting a useful payload clear out to Saturn! / THE EDITOR

On May 8, 1962, at Complex 36 on Cape Kennedy, the three big engines of an Atlas rocket booster flamed to life. The support and hold down pins held the straining vehicle firmly anchored to its base for one long second, and then the engines reached full thrust and completed the launch release sequence. The pins retracted and the mighty Atlas rose smoothly into the air, carrying aloft the first hydrogen-powered vehicle in the U.S. rocket program, the controversial and highly troubled Centaur.

At the cry of "Lift-off!" pandemonium rang through the nearby blockhouse. The Atlas-Centaur vehicle had been sitting on the launch pad more than a year, and the launch crew was almost deliriously happy to see it fly at last. The monitors were reporting a normal flight, the three big engines of the Atlas boosting the presently dormant Centaur second-stage rapidly into the sky. But while the elated engineers were shaking hands and congratulating each other the vehicle reached plus 54 seconds into the mission, and a sudden yell of "Missile blew up! Missile blew up!" came from one of the observers at the periscopes. The clear Florida

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skies were suddenly filled with flame, first white from 5,000 gallons of burning liquid hydrogen, then red and black as the Atlas broke up and dumped its kerosene and liquid oxygen into the conflagration.

Later analysis revealed that aerodynamic pressure on the Centaur had burst the weather shield fairing at the junction of the nose shroud and liquid hydrogen (LH_2) tank insulation panels. The protective panels had ripped off, exposing the walls of the LH_2 tank to tremendous air resistance. These walls, made brittle by the −423°F liquid they contained, ripped open, and the first attempt to test a hydrogen-burning propulsion engine in flight ended in fiery failure. The bugs that live at −423°F had won the first battle, and their objection to extermination was written in smoke across the sky.

Centaur, a pioneer in rocket technology, had had so many troubles prior to that first flight that many experts felt the designers were attempting an impossible forward leap in the state of the art. After the spectacular explosion that destroyed that first vehicle before the engines had a chance to ignite, the Centaur program received the most searching examination and evaluation in rocketry's short history. Everyone concerned, from Congress and NASA down to the builders of the vehicle, General Dynamics/Convair, thoroughly reviewed and reevaluated every phase and aspect of the development program. The end result was to confirm the urgent need for a hydrogen-powered, upper-stage vehicle such as Centaur, and assign the new bird a crucial role in the Manned Lunar Landing program announced in May of 1961 by President Kennedy. The Atlas-Centaur combination had to get the 2,200 pound Surveyor spacecraft to the moon.

The general consensus of the scientific minds who investigated the Centaur program was that nothing was wrong with the vehicle except engineering problems which could be solved by good design and careful testing. The engineering experts associated with the various investigating bodies were more cautious—they were well aware that Centaur was moving into a new technology, and old answers would not apply—but they had to agree that development was now an engineering proposition. And thus began one of the most frustrating and difficult series of flight tests ever seen at Cape Kennedy. The scientific community had furnished the concept . . . but the problems were solved by working engineers, and solved slowly and painfully. The application of a scientific discovery or concept to produce a working piece of machinery frequently requires a major forward movement in supporting technology. In the Centaur program the use of hydrogen demanded almost

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one giant step too many!

Why LH_2 as a fuel? Why buy all the trouble involved with trying to make practical use of a highly inflammable and volatile substance with a temperature of −423°F? The answer, long known to scientists, lies in the basic principles of rocket propulsion and the physical properties of hydrogen. A rocket's forward thrust is obtained from the forceful expulsion of exhaust gases to the rear, producing a reaction on the rocket body proportional to the momentum imparted to the ejected matter. In a chemical rocket engine the energy of the fuel and oxidizer converts to thermal energy by a combustion process. The gases resulting from propellants burning in a combustion chamber reach a very high temperature, producing very rapid expansion. The resulting pressure forces the hot gases through the converging section of a rocket nozzle and into a narrow throat. From the throat area the combustion products expand through the diverging section of the nozzle and are expelled from the open end at tremendous speeds. The high velocity of this exhaust mass causes a momentum change and produces forward thrust. Continuous injection of oxidizer and fuel maintains the combustion process and keeps the thrust steady.

The temperatures achieved in a rocket's combustion process are usually very high, on the order of 5,000 to 7,000 degrees F, and the exhaust velocities of the accelerated gas particles may be as high as 14,000 feet per second. Both the combustion chamber temperature and the velocity of the gas jet are very important determinants of the overall performance of a rocket-engine system.

By the laws of thermodynamics a rocket's exhaust velocity increases directly with the square root of the product of the combustion chamber temperature, Tc, and the exhaust gas constant, R. For a particular exhaust gas the constant R is equal to 1545/m, where m is the molecular weight of the combined gases. This means the exhaust velocity is directly proportional to the square root of the combustion chamber temperature, and inversely proportional to the square root of the molecular weight of the exhaust gas, or $V = \sqrt{Tc/m}$. Hydrogen has the lowest molecular weight of any known substance, and when used as a rocket fuel with any given oxidizer the exhaust gases will be discharged with the greatest velocity. Other fuel and liquid oxygen (lox) combinations have chamber temperatures ranging from 4,500 to 6.500 degrees F, and exhaust gas molecular weights of from 18 to 24 pounds per mole. The chamber temperature of a hydrogen-lox combination runs in the same range, but the molecular weight of the exhaust gases drops to between eight and ten pounds per mole, giving this combination by

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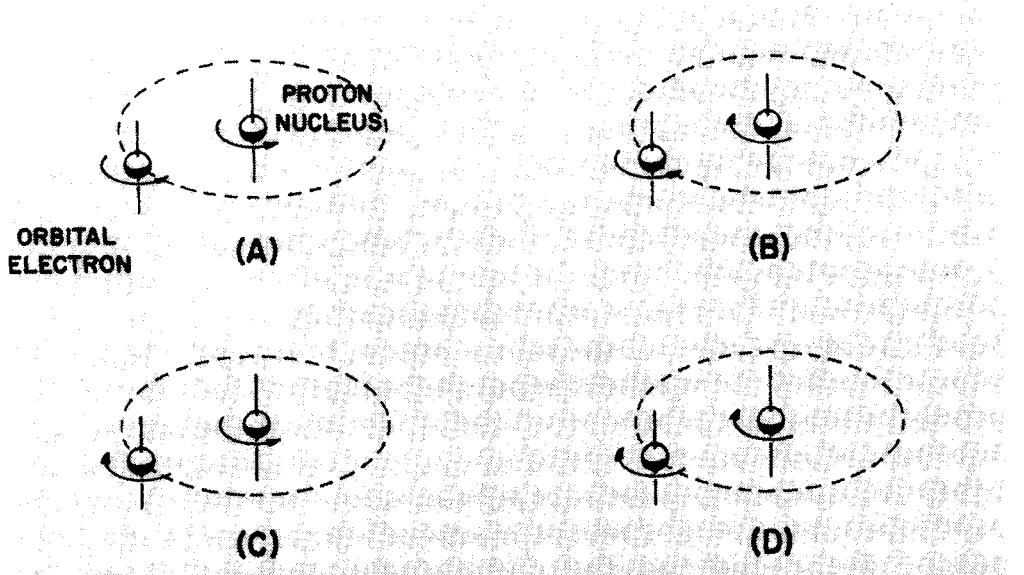

Figure 1. The Four Forms of the Hydrogen Atom.

far the highest exhaust velocity.

Hydrogen, then, is the ideal rocket fuel in terms of work achieved for a given quantity of propellant. This is the primary reason LH_2 was chosen as the fuel for the two upper stages of the giant Saturn V moon rocket, and why the first atomic-powered rocket engine will heat and expel hydrogen gas to obtain its thrust.

And why liquid rather than gaseous hydrogen? The deceptively simple answer is that hydrogen burns as a gas, but is tanked on board as a liquid because of its expansion ratio of 750 to one. Expanded, the hydrogen in the 5,000 gallon Centaur tank would fill an unpressurized cylinder 50 feet in diameter and almost 500 feet long. Compressed gas would require strong, heavy cylinder walls. This would lower the vehicle's efficiency, since the most important parameter determining a rocket stage's total performance is the ratio between the lift-off weight and the burn-out mass. A rocket's thrust remains constant, but its weight steadily declines as propellants are burned. The less the basic vehicle weighs in proportion to the propellants, the higher the final velocity. An "optimum design" vehicle uses the lightest safe tank walls possible, replacing every pound saved with additional propellants.

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Hydrogen is the most abundant element in the universe, but exists in nature primarily in combination with other elements. Free elemental hydrogen is a mixture of two isotopes, regular hydrogen with an atomic mass of one and deuterium with a mass of two. This mixture, with an atomic weight of 1.008, is, of course, mostly hydrogen, with a ratio of approximately 6,400 to one. Another very rare isotope of hydrogen, tritium, has an atomic mass of three, is radioactive, and has an occurrence of about one in a billion. Free hydrogen exists as a diatomic molecule in nature, and in two different forms. These are determined by the relative direction of the nuclear spin on the individual hydrogen atoms. The combination of two hydrogen atoms with the nuclei spinning in the same direction—parallel spin—yields a molecule of ortho-hydrogen, while an anti-parallel nuclear spin combination yields a molecule of para-hydrogen. This is illustrated in Figure 1.

While all four of these hydrogen atoms can exist, only those with opposite electron spins can combine to form the hydrogen molecule H_2. In Figure 1 then (A) could combine with (C) or (D), but not with (B). Taking the first case as an example, when (A) united with (C) the proton nuclei would be spinning in the same direction, and the resultant molecule would be ortho-hydrogen. If (A) united with (D) the nuclear spins would be antiparallel, and a para-hydrogen molecule would result. There is a significant energy difference between these two molecules, and the ortho to para conversion, which yields heat, is spontaneous when the temperature is reduced. At ordinary room temperature normal hydrogen is stable at a ratio of seventy-five per cent ortho and twenty-five per cent para. The conversion process at the liquid temperature is slow, but still generates enough heat to reevaporate the liquid hydrogen at the rate of one per cent an hour, an intolerable amount.

The first major trouble encountered with LH_2, then, was to find a means of converting free hydrogen into the para form *before* liquefying it. In 1953 the National Bureau of Standards solved the problem in the laboratory by finding a catalyst. On the production line several American companies came up with more efficient large-scale catalysts. Air Products And Chemicals, Inc. used chromium oxide on alumina supports, and the Linde Company used iron hydroxide gel. Both produced parahydrogen in sufficient quantities for commercial production. Since that time Air Products And Chemicals, Inc. has started using a more effective—and proprietary—catalyst, and the conversion process is no longer a problem.

The first major step toward using

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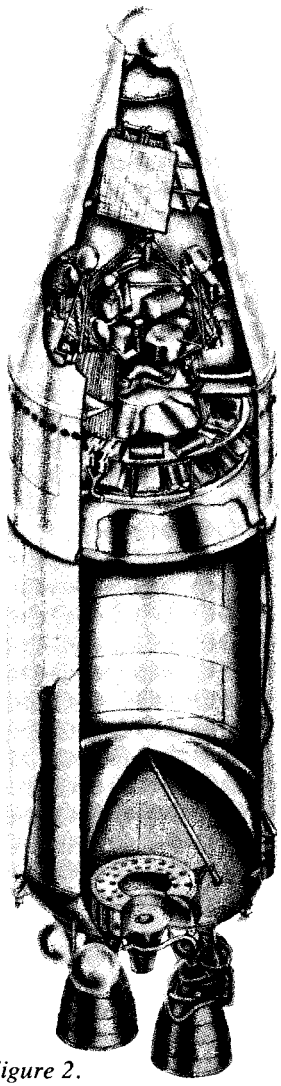

Figure 2.
The Basic Centaur Vehicle (including a Surveyor in the nose fairing.)

LH_2 as a rocket fuel began in 1956, when Pratt & Whitney Aircraft Corp. started developmental work under an Air Force contract. In five months P&W had modified a standard J57 aircraft engine to operate on LH_2, and within a year had developed a completely new hydrogen jet engine called the 304. One of their major contributions was a new fuel pump, having an axial inducer and two back-to-back stages, producing a pumping rate of about four lb/sec of LH_2 at 1,000 psia. Within this same time period the Advanced Research Projects Agency (ARPA) asked Convair for a proposal for a high-energy hydrogen powered upper-stage vehicle.

The first Centaur concept originated by Convair utilized a pressure-fed engine system, to avoid an anticipated lengthy and troublesome pump development program. ARPA then notified Convair of P&W's accomplishment, and asked for a modified proposal based on a vehicle using two 15,000 pound thrust pump-fed engines. The resulting modified proposal led to the granting of a contract for the Atlas-Centaur combination vehicle in November of 1958. The work already done by P&W resulted in their obtaining a contract to develop and manufacture the oxygen-hydrogen engines.

The initial increment of the Convair contract was basically to determine if an oxygen-hydrogen powered upper-stage was feasible,

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and Centaur funding was limited. This meant the proven Atlas structural design concept of pressure-stabilized integral tank construction had to be used for Centaur, to permit utilization of the existing Atlas facilities and tooling. This also determined the Centaur tank diameter, which had to be ten feet to mate with the Atlas booster. The lifting capabilities of the booster dictated a total weight for Centaur of about 30,000 pounds. This weight also resulted in a very good staging ratio when the Atlas engines burned to propellant depletion before separation and Centaur ignition. The Centaur design (see Figure 2) was thus based on Atlas configuration, construction techniques, and capabilities.

The task of designing the Centaur began, and a host of questions swamped the engineers almost immediately. How do you insulate an exposed hydrogen tank surface of over 500 square feet while tanking and launching? What about the heat generated by air resistance as that Atlas booster pushes Centaur to better than Mach 8 before the bird leaves the atmosphere? Would the lapped, spot-welded type of tank construction used on Atlas really contain the superfluid, supercold LH_2? What are the behavioral characteristics of LH_2 under the zero gravity conditions encountered during a coast phase? The answers to these, and a hundred other major questions which could not even be foreseen, were to come hard in this program.

When the basic Centaur design was completed the vehicle bore a strong structural resemblance to its forebear, the Atlas. It utilized the "integral tank" concept, in which the outer skin of the rocket serves as the wall of the propellant tank. On the first Centaur this single skin averaged only 0.010 inch thickness. Both vehicles contain no framing or stiffening structure, and their skins are far too thin to provide structural rigidity. The two tanks are kept pressurized at all times when a vehicle is supporting its own weight, a concept called the "balloon" structure. This is the basic design of the "optimum weight" vehicle, in which performance is improved by achieving the highest possible ratio between propellant weight and empty vehicle weight. The overall design has been compared to that of a football, where wall shear strength and internal pressure produce a very light but rugged unit.

A Centaur's tanks are depressurized only when the vehicle is sitting on the pad in "stretch" atop the Atlas. In this condition it is attached by a suspension system to overhead beams, while the Atlas is locked at its base by hold-down pins. An upward pull of 14,000 pounds is exerted on the overall vehicle. If this axial tension load is not applied before the tanks are de-

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pressurized, it will collapse—like an empty football.

The Centaur LH_2 tank structure consists of a stainless steel cylindrical section capped on each end by elliptical bulkheads. The upper bulkhead curve is concave from the interior in the normal configuration for a pressurized vessel, but the lower, which separates the LH_2 tank from the nearly circular lox tank, is convex. This permits better utilization of space, which is occupied by LH_2, but brings new requirements. Not only must tank pressures be maintained to prevent collapse, but pressure in the lox tank must be greater than that in the LH_2. If a reverse pressure situation occurs, the thin bulkhead will be forced backward—probably destroying the bulkhead and certainly ruining the structural strength of the vehicle. Special handling techniques, both in the factory and on the pad, are required to ensure structural integrity.

Welded brackets support the various systems which must be attached to the aft lox bulkhead, the forward LH_2 bulkhead, and the exterior tank walls. Steel rings welded to the ends of the forward and aft cylindrical section provide a seat for the nose fairing and the interstage adapter. Two light-weight transfer pumps powered by hydrogen peroxide are mounted at the bottom of the lox and LH_2 tanks. They are necessary because the thin walls will permit internal pressures of only 20 psia for LH_2 and 30 psia for lox, and these must be increased to the higher pressures required for proper start and operation of the engines.

Attitude control of the Centaur during the zero gravity coast phase is maintained by small rocket jets, also using hydrogen peroxide (H_2O_2) as a monopropellant. The superheated team generated when ninety per cent H_2O_2 is exposed to a rapid-action catalyst in a confined area can be jetted out a nozzle, as well as against the vanes of turbines such as those that power the two tank pumps. This same system provides propellant control by supplying a small but constant thrust when the vehicle is in the zero-gravity condition, utilizing a separate set of thrusters.

Insulation of the exterior, cylindrical sides of the LH_2 tank is accomplished by a set of four insulating panels, which can be jettisoned on command. These panels are of a "sandwich" styrofoam construction, with a honeycomb fiberglass interior reinforcement. The top and bottom of the sandwich is the fiber-glass sheet formed to the tank and protuberance contours. The top bulkhead of the LH_2 tank is insulated by styrofoam sections bonded to the stainless material. The aft bulkhead of the lox tank is insulated from solar radiation during coast by a thin fiber-glass shield painted with a special high reflectivity white paint.

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The spacecraft payload must be protected from aerodynamic forces and heating during boost flight. Any particular spacecraft must have a relatively constant thermal environment and be protected from contamination. For Centaur this is accomplished by a low-drag nose fairing, or shroud, which totally encapsulates the spacecraft. It incorporates a thermal bulkhead to separate the spacecraft environment from the electrical equipment on top of the Centaur LH_2 tank. The nose fairing, like the insulation panels, is blown apart and jettisoned when the vehicle is completely out of the earth's atmosphere. See Figure 2 for an illustration of the basic Centaur, including a Surveyor spacecraft inside the nose fairing.

Thrust vector control is maintained by gimballing the main engines with hydraulic actuators, two on each engine, which receive inputs from the vehicle guidance and autopilot systems. Each engine has its own separate hydraulic power supply, run by an accessory power takeoff provided on the engine's lox pump shaft.

A propellant utilization system is necessary to ensure that all lox and LH_2 are burned and do not remain aboard as dead weight. This is accomplished by constantly measuring the quantities of lox and LH_2 in the tanks during engine burn, comparing them, and changing the actual mixture ratio—over a narrow band—by slightly opening or closing the main lox valves in the engines. This means the engines sometimes operate on a less than optimum thrust mixture ratio, but the decrease in thrust is small and the gain in performance by elimination of dead weight is large. A reserve quantity of both propellants is provided in case of unexpectedly low engine performance, but this is held to a minimum. When the Centaur engines ignite for a second burn after a coast phase in orbit they are pushing the lowest possible weight of vehicle and spacecraft—another application of the "optimum weight" concept.

The Centaur uses gaseous helium under pressure for actuating the main engine valves, pressurizing the hydrogen peroxide bottle, step-pressurization of the main tanks, and various purges. This is provided from a spherical titanium bottle.

Both lox and LH_2 are constantly vaporizing, or "boiling off." The tank pressures necessary to ensure the Centaur's structural integrity must be maintained, but excess pressure prevented by venting the boiloff gas. This balancing function is performed by on/off vent valves, normally automatic in operation but with a lock-closed capability. These valves are designed to vent gas, and a small "ullage" or vapor space is required at the top of each propellant tank to prevent liquid from reaching them. This ullage is provided during tanking by means

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of a point sensor system in each vehicle tank which provides the blockhouse with liquid level indications.

The hydrogen vent valve is placed at the top of the liquid hydrogen tank, in the electrical equipment compartment located between the liquid hydrogen forward bulkhead and the nose fairing/spacecraft thermal bulkhead. This compartment provides mounts for the guidance, autopilot, electrical and telemetry equipment, and must be maintained at about 50°F. This is done by supplying the compartment with conditioned gaseous nitrogen from a unit located on the ground. The hydrogen gas, still at about −420°F, flows from the vent valve through an insulated duct to the hydrogen vent fin on the nose fairing. The end of this fin, which extends well into the exterior air, is provided with a disconnect joint connection to a pipe on the retractable boom. On the boom a pipe conducts the gas to a tall vent stack, where it emerges and dissipates too rapidly for the small amount present to become a hazard.

One major Centaur problem which vividly illustrates the design difficulties caused by the choice of LH_2 as a fuel had the distinction of being solved quietly on the ground rather than spectacularly—and expensively—in the air. This was an unglamorous but vitally important item, the double-wall intermediate bulkhead used to separate the LH_2 tank from the lox tank (and it is worth noting that the LH_2 tank contains about five times the volume of the lox—but LH_2 is so light the lox outweighs it five to one when both tanks are filled). The lox tank material, of a heavier gauge than the LH_2 tank, incorporates a spring ring on the upper end to permit expansion and support of the convex end of the LH_2 tank. In order to keep LH_2 from boiling off by convection warming from the −299°F lox tank skin, a vacuum was needed in the space between the double walls. Since the lox tank upper wall was flexible this meant some solid material had to be used as a separator. The solution was to place a fiber-glass covered styrofoam matt, approximately 0.2 inch in thickness when compressed, within the cavity. The styrofoam offers a comparatively solid resistance but is actually highly porous. An ingenious system was devised whereby the supercold properties of LH_2 were utilized to advantage. The intermediate bulkhead cavity, including all the airspace within the fiber glass open to the surface, is first evacuated, then refilled with gaseous nitrogen through a steel tube running to the exterior of the vehicle. The unit is then sealed by welding. When the LH_2 tank is filled the upper surface of the bulkhead becomes supercold, and the thin space between it and the lox bulkhead cools enough to freeze the gaseous nitrogen. The

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nitrogen condenses into a solid, and since the area is sealed a vacuum is produced. This "freezing out" method of producing a vacuum is called cryopumping. It is, simply, a vacuum produced by extremely cold, or cryogenic, temperatures.

The solution, as always, gave birth to a new problem. When the first bulkheads were tested with LH_2 the vacuum would suddenly disappear. After the test the bulkhead could be pumped down with a vacuum pump, and the vacuum would hold! Obviously hydrogen was leaking through the upper shell, or lox through the lower. The culprit, of course, was LH_2. This was the Centaur program's first experience with a quality of the light liquid that was to furnish them with a whole new set of frustrations in the days ahead—LH_2's terrible "creep ability."

This problem resulted in the exhaustive investigation and series of retests that were to become standard procedure for Centaur. The bulkhead design was similar to that used on the Atlas, and so were the inspection techniques, which had proven capable of detecting leakholes down to 0.0001 of an inch. It was finally discovered that LH_2 temperatures opened minute holes *less* than 0.0001 inch, and the liquid's extremely low viscosity let it creep through the holes it had made, flash to a gas, and destroy the vacuum. These holes disappeared when the LH_2 was removed and the steel warmed to a more normal temperature. This was a bug that LH_2, and only LH_2, could produce to harass an already overburdened engineer.

Another and related trouble area was that LH_2, when dumped on the thin stainless steel bulkhead during tanking, created uneven stresses by temperature shock, causing permanent deformation and buckling of the material. These two problems gave the Centaur designers headache after headache—as did all Centaur problems—through late 1961 and early 1962. They were solved, as were most of Centaur's problems, by dogged work and effective but hardly genius-inspired changes. During the Centaur redesign that followed the first colorful flight failure, a series of engineering modifications were made which proved capable of stopping the tiny leaks. The wrinkles formed as a result of the cold liquid splashing on the bulkhead still existed, but here a simple change in tanking procedure provided an easy solution. A prechill operation was initiated for LH_2 tanking. In current practice LH_2 flows from the pad storage dewar at a low rate, expanding to a cold gas before it reaches the vehicle's tank. The flow rate is gradually increased, and the gas becomes colder and colder as it flows into the tank and out the automatic vent valve. Temperature reduction in the bulkhead tank walls is steady but gradual. When $-400°F$ is

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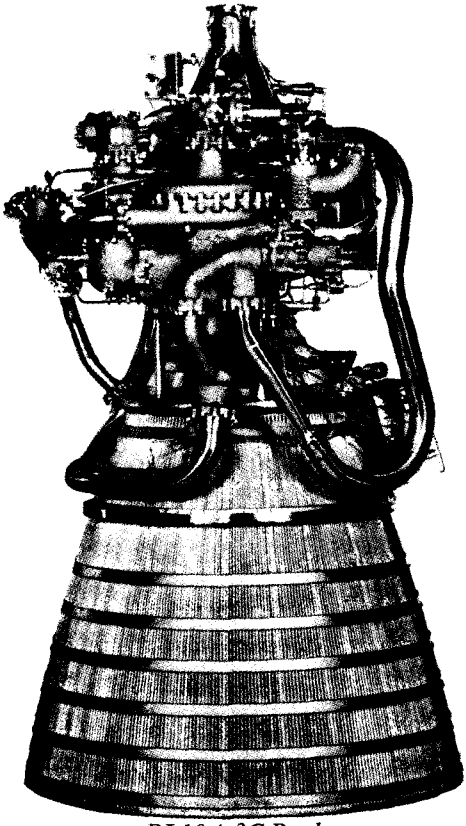
reached full-flow liquid tanking is started, and the additional 23°F drop does not damage the bulkhead.

Centaur's major advance in rocket design was its propulsion system. The first P&W liquid hydrogen engine, designated the RL10 (see illustration), utilized new and ingenious design concepts. One of the major innovations was to take advantage of the high specific heat and extremely low critical temperature and pressure of LH_2 in order to obtain energy directly from the hydrogen itself. This energy, extracted from the hydrogen liquid-to-gas conversion process, is used to power the turbine-driven LH_2 and lox pumps.



RL10A-3C Rocket Engine (67½" high)

The usual method of driving a rocket engine turbopump is by a separate gas generator, which diverts a small quantity of the fuel and oxidizer flow from the engine and burns it to produce hot gases needed to spin the turbine. The energy from these gases is not expanded through the rocket's nozzle and little thrust is produced, lowering overall performance. No gas generator is used in the RL10 engine. The liquid hydrogen is vaporized within the engine, and the resulting increase in kinetic energy provides the power used to drive the turbine, which turns both the LH_2 and lox pumps and provides the power for the hydraulic actuators which gimbal the engines as well! *All* the hydrogen gas is burned in the engine chamber, and is exhausted through the engine nozzle, producing thrust with maximum efficiency.

The engine starts when LH_2 at low pressure flows through the pump and into the thrust chamber tubes. Contact with the comparatively hot tubes completely vaporizes the liquid, and the resulting high velocity gas—caused by that expansion ratio of over 700 to one

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—is expanded through the turbine, spinning the impeller up to 30,000 rpm in about one second. The turbine drives the two-stage LH_2 pump through a common shaft, and the lox pump is driven by a reduction gear train, from the same shaft, at 12,000 rpm (see Figure 3). The hydrogen gas, still traveling at a high velocity, flows directly from the turbine to the engine chamber, where it is mixed with the still liquid oxygen and ignited.

The rapid spin-up of the turbine converts the cycle from the low pressure start phase to the high pressure full-power phase. It is, in effect, a "bootstrap" cycle, since the pumped hydrogen is providing the power to continue to pump itself. Once the turbine is turning the process is continuous, provided that ignition occurs and heat is produced in the thrust chamber. Without combustion the supercold gas will quickly extract all heat from the chamber tubes, the liquid-to-gas conversion will cease, and the turbine will stop.

A major hydrogen problem becomes apparent at this point. When the LH_2 reaches the much warmer pump it immediately flashes to a gas. The pump must be reduced to an operating temperature near that of the liquid hydrogen prior to starting, a normal requirement for all cryogenic centrifugal pumps. The RL10 designers decided to use the same principle already proven on some liquid oxygen pumps, including those on Centaur, which is to open the engine pump inlet valves and let the liquid and gas flow through freely several seconds prior to engine start. The extremely cold fluid soon cools the pump enough to stop the conversion process, as mentioned above. Overboard cooldown valves were installed downstream of both the first and second stages of the LH_2 pump, to allow this flow-through process. After the correct pump operating temperatures are reached a start sequence closes the overboard cooldown valves and opens the main fuel valve, returning the system to the regular pattern.

This solved the cooldown problem but, as was to be typical of Centaur development, the solution itself brought new problems. Dumping hydrogen out the overboard valves would have to be accomplished after separating the Centaur from the Atlas, or the interstage compartment, already receiving oxygen from that system's cooldown, would rapidly fill with an explosive gas mixture. The hydrogen pump required a 30 second prechill flow. If this operation could not start prior to separation, vehicle performance would suffer, both from gravity pull during unpowered flight and the loss of unburned propellant. There being no immediately available alternatives, however, a decision was made to proceed, and the AC-1 flight did in-

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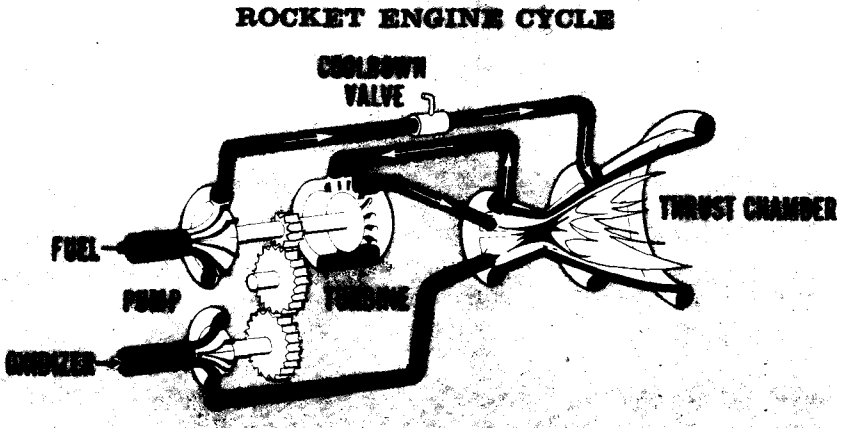

Figure 3. Propellant Flow Diagram of the RL10A-3C Rocket Engine.

corporate the early separation and inflight cooldown system. Its merits were never determined.

After the AC-1 failure and subsequent investigations the entire vehicle underwent a thorough design study, by both the Lewis Research Center and Convair. Major changes were made in the basic structural plan, resulting in a much stronger but heavier bird. The decision that Surveyor would be Centaur's first mission posed another weight problem; at 2,200 pounds minimum Surveyor was straining Centaur's design capacity for a lunar mission. Vehicle performance had to be improved, and the most logical method was by weight reduction. At this point someone came up with an extremely simple but potentially effective idea. Why not precool the hydrogen pump on the ground and let its mass maintain the chill through the 240 seconds of Atlas burn time? An inflight cooldown would still be required, but one of only a few seconds duration. This would shorten the 30 second "dead" period between separation and engine start, and retain many pounds of fuel to be burned rather than dumped overboard.

The idea was so obviously good it was immediately adopted . . . and the new set of problems promptly appeared.

In the RL10 engine the LH_2 pump inlet valve could not be opened without simultaneously opening the matching lox inlet valve. This would create, on the

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ground, the same mixture of combustible gases in the interstage compartment the designers were trying to avoid in flight. The engine would have to be modified to permit independent operation of the hydrogen inlet valve, and the vented hydrogen collected and safely dissipated.

These problems were recognized by the Lewis Research Center, and its implementing order to Convair stated that if the problems associated proved insurmountable the ground cooldown would be abandoned in favor of the original inflight overboard cooldown sequence.

About a month after the original order someone at Lewis had a brainstorm, and the Center issued a new directive ordering the substitution of liquid helium for LH_2 in the ground cooldown program. There was a solid basis for this decision. Helium is completely inert, and at a temperature of −452°F is even colder than LH_2. It is so cold, in fact, other gases freeze on contact and exist in the fluid as solids. The Lewis Research Center had been using helium in their space power simulation chamber on several research programs, and had done extensive developmental work. There were problems associated with producing, handling, transporting and storing this coldest of all liquids, but these could be solved. The advantages made the application effort seem more than worthwhile. Numerous difficulties arose, as usual, but they were resolved with dispatch and a helium dewar was soon located at the launch site, near the base of the umbilical tower.

In practice the light and very fluid liquid helium is forced up to the engines by pressurizing the dewar with helium gas generated by a vaporizer. Transfer pressure is regulated to about 50 psia, which is above the critical pressure for helium. The helium is actually in a mixed phase during transfer, but becomes all gas at the point where it enters the engine pumps. This gas, however, is about −420°F. An independent piping system feeds the cold helium gas into the first stage of each hydrogen pump, and from there it flows through both the first and second stages and out the engine overboard cooldown valves; it is then vented to atmosphere.

The entrance and exit ports utilized for helium flow through the hydrogen pump were already in existence; the short inflight cooldown still required was adequate for the 124°F warmer oxygen pumps without a ground cooldown. No engine redesign was necessary, and only inert helium is dumped in the vicinity of the vehicle.

The first redesigned Centaur flight vehicle, the AC-2, arrived at Cape Kennedy in September of 1963. Many engineering changes had been made in addition to the general "beefing up." A major change intended only for the one flight was the addition of "battle-

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ship" insulation panels, very heavy in weight and profusely instrumented. The insulation panels and nose fairing would not be jettisoned, since the designers wanted to gather as much information as possible on what happened to them in flight.

Some other major engineering changes were: (1) The addition of a secondary hydrogen tank boiloff valve, in case boiloff rates exceeded the capacity of the primary valve. (2) The extension of the hydrogen vent fin on the nose fairing to a length of 50 inches, to prevent hydrogen gas from getting into the vehicle's slipstream and being conducted to the flaming Atlas engines. (3) Increased tank skin gauge, of up to 0.016". (4) The use of flexible linear shaped charges to separate the Centaur stage from the interstage adapter on the Atlas. (5) Incorporation of a new single burn direct ascent mission sequence. This last change marked an important turning point for Centaur.

It was recognized by all concerned that the problems associated with controlling LH_2 in a zero gravity condition, and restarting the engines after a coast phase in orbit, were going to be rugged ones. In order to complete the Surveyor mission, which was to obtain close-up photographs and bearing strength information on the lunar surface, development time had to be shortened as much as possible. Henceforth Centaur was to run two concurrent R&D programs, one devoted to the complex problems associated with two separate burns, a second aimed at solving the slightly less complicated troubles involved in simply making the Centaur work. The two-burn capability gave the Centaur much longer launch windows and far more mission versatility . . . but time was running out for Centaur to prove itself.

Centaur had been designed from the beginning as a two-burn vehicle, for excellent reasons. A spacecraft usually weighs in near the vehicle's maximum designed lifting capacity for the particular mission, whatever it may be. Since little excess power is available the vehicle must lift off at a time when the chosen target is in an optimum orbital relationship to earth. The turning of the earth on its axis changes this optimum time fairly rapidly, providing short "launch windows." The vehicle must be above a certain point on the earth's surface, moving at a set speed and in a predetermined trajectory, when vehicle thrust ends and the spacecraft is left to "coast" for the remainder of its trip. On a direct ascent the vehicle lifts off and moves to this point in continuous powered flight. On a two-burn mission the vehicle lifts off, achieves low earth orbit, and "coasts" toward this point. The engines are then restarted and the same trajectory and speed obtained when the point is reached. Disre-

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garding "dogleg" maneuvers and other complicated orbital mechanics, this simply means that a variable factor has been introduced, the length of the coast period.

In Centaur's lunar missions this coast period has a theoretical possible length of from five to twenty-five minutes, allowing the amount the earth's surface has moved toward the east to be compensated for by shortening the coast period. This not only provides longer and thus less restricted launch windows, but more days during a given year when a launch may be attempted for almost any selected target. For example, in January of 1967 there were nine days during which a direct ascent Surveyor flight could have been launched, with an average window length of fifty-three minutes. This contrasts with twenty-four days for the two-burn vehicle, with an average window length of over one hundred ten minutes.

A lunar, or planetary, launch requires support from most of the Air Force Eastern Test Range stations, one or more tracking networks, the JPL Deep Space Network stations, and various ships and planes. This support is very expensive, and, if a minor problem delays a launch until the window is past, a great deal of money has been wasted. Obviously, doubling the length of the window decreases the chance of this happening. On certain planetary missions, where optimum windows occur only during a few days out of certain years, a missed launch can mean a delay of years before the next possible attempt.

Atlas Centaur 2 was launched November 27, 1963. To the immense surprise of everyone concerned the flight was completely successful. When the Centaur's engines ignited and carried the vehicle into earth orbit a significant milestone was passed in space technology—the first use of LH_2 as a fuel in a space vehicle. The Centaur's performance proved the correctness of the scientific concepts incorporated in the propulsion system, and all remaining problems were for the engineers to solve.

The heavily instrumented insulation panels proved that the design for those on the AC-1 vehicle had been inadequate. New panels were designed, this time an inch thick, of heavier fiber glass reinforcement, and weighing about 1,200 pounds, an unwanted increase of almost 800 pounds over the originals.

Jettisonable insulation panels were new with the Centaur, and were one of the several forward steps Centaur took in overall rocket design. In line with the continuing "optimum weight" theme the four panels were to be released as soon as the air thinned enough to eliminate aerodynamic pressure and heating as potential hazards. In Centaur's case this worked out to about T+180 seconds into the flight, or 300,000 feet altitude. For each fifteen pounds of insulation

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weight jettisoned at this point, the vehicle would gain about one pound of payload capacity. It was absolutely essential that the jettison system work.

The AC-3 vehicle was to incorporate the new panels, and actually test the jettison system for the first time. This flight, another single-burn mission. was scheduled for March of 1964. In the meantime, in line with an exhaustive ground test program recently instituted by Lewis Research Center, an extensive series of jettison tests were performed by Convair engineers at their Point Loma facility in San Diego. During one of the full-scale tests, with a partial tank of LH_2, one of the four panels failed to release on command. The jettison system had operated correctly during earlier tests at ambient temperature. Investigation revealed that the panel had actually frozen to the tank wall, despite the small gap between the two.

Another hydrogen bug had appeared. The LH_2 tank skin was so cold it was actually liquefying nitrogen and oxygen molecules in the air, then freezing them into solids and forming a strong bond between the insulation panels and the tank wall. This possibility had occurred to the panel designers, and they had allowed for it by devising a purge ring circling the LH_2 tank at the bottom of the insulation panels. In operation this ring released a flow of helium gas into the gap between the panels and tank skin, and the light gas, rising uniformly around the tank, insulated it from contact with ambient air. Since hydrogen cannot freeze helium the engineers had felt this was an adequate precaution.

The basic design for tank-to-skin isolation was indeed a good one, but the system had failed because the helium flow rate had been set too low to remove all other gases from within the gap. The fix, once the problem was analyzed and understood, was to increase the flow of helium gas from sixty to one hundred twenty pounds an hour, plus installing an additional bottle on the vehicle to continue the purge after lift-off.

The insulation panel test program at Point Loma was completed, after much frantic work, in time for the redesigned insulation panels to be flown aboard the AC-3 vehicle. This flight was to be a repeat of AC-2, except for jettisoning the panels.

The bird was launched on June 30, 1964. Atlas performance was normal, and several hundred people started breathing again when the insulation panels jettisoned perfectly during Atlas sustainer flight. Atlas-Centaur separation was good, and the Centaur engines ignited correctly. That made it seem as much hard luck as inadequate design when a new weak point appeared almost immediately; this

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one, for a change, not attributable to LH_2. A drive coupling in the hydraulic system, one which transmitted power from the lox pump accessory drive to one engine's main hydraulic pump, sheared about four seconds after the Centaur engines started. The resulting loss of ability to gimbal that engine threw the vehicle out of control, and orbit was not achieved.

No one felt particularly disheartened by the freak failure of AC-3. The panels had proven themselves, and a minor redesign would take care of the hydraulic problem. The launch people were far more worried about AC-4, which was to be the first vehicle to return to the original design concept and attempt to restart the Centaur engines after a coast phase in orbit. It was also the first to carry a mass model of the Surveyor, a model somewhat lighter than the actual spacecraft.

The major problem areas with AC-4 were seen as achieving control of the extremely light and very fluid LH_2 for twenty-five minutes of zero gravity coast flight, and a successful second cooldown and restart of the Centaur engines. Since both LH_2 and lox could be fed through the pumps and out the cooldown valves into space, the only problem was in determining the minimum flow necessary to reach the desired temperature, as far as inflight cooldown was concerned. Keeping the propellants at the bottom of their tanks was something else again, especially where LH_2 was concerned. The method chosen during the Centaur redesign study was to maintain a small but positive thrust on the vehicle at all times, causing both propellants to settle to the bottom of their tanks and remain there. This force was to be supplied by two small (two pound) hydrogen peroxide engines, of the same design as those on the regular attitude control system.

Under zero gravity conditions a rocket responds to even small thrust pressures, and since the vehicle would be in this condition for up to twenty-five minutes the accumulated thrust exerted by discharging the hydrogen boiloff gas would be considerable. To prevent this jet from applying a disturbing torque to the vehicle two exit ports were built opposite each other, and their thrust, theoretically, would balance and cancel each other out. A baffled plenum chamber, dubbed the "septic tank" by the launch crew, was installed on the exit of the vent valve, with two ports directly opposed to each other. The system had only to be proven in practice.

AC-4 lifted off on December 11, 1964. Again the Atlas booster performed well, and Centaur first burn seemed perfect. The vehicle obtained a low earth orbit with no difficulty, and all instruments indicated good stability during the period immediately following engine

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cutoff. However, LH_2 had moved forward in its tank due to transient forces experienced during engine shutdown. The small hydrogen peroxide rockets had come on as programmed and were performing properly, but the thrust proved insufficient to settle the LH_2 to the bottom of its tank. The LH_2 boiloff proceeded in a normal fashion, with the result that pressure built up until the vent valve had to open. When this occurred the vehicle suddenly yawed. Apparently *liquid* hydrogen which was floating in the tank had entered the gaseous vent system, and when it reached the vacuum of space it expanded and produced a thrust greater than the attitude control jets could handle. The vehicle's sideways movement caused further shifting of the propellants, aggravating the condition, and the disturbing thrust increased. In a few minutes the bird was tumbling end over end through space, although all other systems functioned normally. The vehicle's spin was centered roughly at the top of the lox tank, forcing the lox to the bottom of its container but LH_2 to the top of its longer tank.

At the end of the coast phase the still functioning autopilot commanded second engine start, but only gaseous hydrogen was available to the tank pump. AC-4 had joined AC-1 and 3 as another discouraging and expensive failure.

AC-5 was programmed to fly less than three months after AC-4, and fortunately this was to be a single burn flight with a Surveyor mass model. The primary objective was to demonstrate the Centaur's readiness to perform the Surveyor mission. The settlement and control problems associated with a zero gravity coast phase and second burn could wait for AC-8, not scheduled to fly for a year. The Centaur had to start payment on its development cost by getting that first Surveyor to the moon. The question of the moon's surface composition, dust-covered or solid, which eminent scientists had been vehemently arguing since the first Ranger success, had to be answered to permit a final design of the Apollo lunar landing module.

Since all the problems associated with a single burn had been solved, AC-5 had every right to be a success. Overall performance had been well established as good, and only a textbook flight was needed to declare the single burn Centaur operational.

The AC-5 vehicle was erected on the launch pad in January of 1965, and during the prelaunch checkout of both Atlas and Centaur the vehicle lived up to the high expectations resting on it by being remarkably free of the usual checkout problems. In the assembly and checkout of a pair of rockets as complex as the Atlas and Centaur a thousand small problems usually arise to plague the launch crew. Leaks will appear in the propulsion

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or pneumatic systems, a fairing fit is out of tolerance, autopilot gyros won't spin up to full speed—the list of possibilities is endless. Few of them materialized on AC-5. Every scheduled milestone date was met. All major tests were completed without difficulty. The launch date had been set for March 2nd, and on March 2nd the bird was ready to fly.

There is an old—meaning it's been around more than five years—axiom among rocket launch operations people: The dirty bird flies best. A "dirty bird" is one that arrives on the pad full of problems, requiring every system to be taken apart, and cursed and studied until the trouble is found. Each system is then put back together, tested, cursed, and operated under stringent performance requirements. The result of this intensive system-by-system scrutiny is that all problems, unless they are so subtle only a flight will bring them to the surface, are found and fixed, usually including many not discovered until the system was opened. After this treatment the bird usually flies "straight."

AC-5 had no problems. This should have alerted a naturally pessimistic launch crew, but all were too happy with the perfect test schedule to start deliberately looking for trouble.

The countdown on March 2nd was as flawless as the tests, and at T-4 seconds the Atlas engines flared to life and started building thrust. At T-1 second all requirements had been met and the release sequence was initiated. The hold-down pins retracted and the bird lifted off, slowly at first but gaining speed with every inch, moving up, up—for five feet. Then incredibly, unbelievably, the 330,000 pound thrust Atlas booster engines died. The *tiny verniers and the 57,000 pound* thrust sustainer burned with power and fury—they were trying to lift 300,000 pounds!

AC-5 settled back on its pad (see illustration), every tank on the vehicle ripped open, and the resulting explosion created an initial fireball 600 feet long, 200 feet wide and over 300 feet high. The burning gas cloud had an expansion velocity of over 3,000 feet/second, and furnished one of the best examples seen at the Cape of why fragile human beings retreat to massively built blockhouses during a launch. No one was injured, other than in feelings, but AC-5 was a mass of blackened rubble, and pad A had suffered major damage and would require extensive rebuilding.

The faithful Atlas had failed, for the first time in the program. Fortunately, enough was left of the propulsion system to permit a failure analysis. The trouble was isolated to the fuel system, in the area between the Atlas RP-1 tank and the booster engine pumps. The evidence indicated that either the staging disconnect valve, or the fuel

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prevalve, had somehow closed, shutting off flow to the engines.

The corrective action, incorporated before the flight of AC-6, was to remove the remote actuation mechanisms from the booster and sustainer fuel prevalves, and replace them with manual valves which could be physically locked open or closed with bolts. These valves did not open and close often enough in checkout for their operation to be a problem. The complicated staging valve, designed to close the fuel line to the booster engines when they are jettisoned, was redesigned, and its supporting structures beefed up.

It had been no fault of Centaur's that this worst-of-all disasters had occurred . . . but Centaur's reputation as the "hard-luck bird" was now secure.

Five months went by before AC-6 was ready, and only that soon because it had been erected on pad B, not previously used. The AC-6 vehicle was almost identical to AC-5, and had the same mission, to prove the Centaur ready for operational duty in the single burn configuration. The Surveyor mass model, however, was a considerably more sophisticated spacecraft, closely matching the true one in size, weight and balance, with a tracking beacon that would let earth ground stations follow it for over twenty hours of flight. The spacecraft was to be injected into a simulated lunar impact trajectory, the so-called "paper-moon shot," in which the target is a fixed and definite point in space which must be reached at an established time. The actual moon is never used as a target except for operational spacecraft. As all Dick Tracy readers know, we have too much debris littering the moon's surface already.

AC-6 had a normal checkout, and, to confound the critics who had said Centaur would "never fly," a completely successful flight. The guidance system, on its first semi-operational mission, performed so well the simulated moon was hit even without the normal spacecraft midcourse trajectory correction. Atlas-Centaur was ready for a live Surveyor.

Unfortunately, Surveyor was not yet alive.

Centaur had taken a giant forward step in rocket technology, but Surveyor had the distinction of pioneering in a brand-new field, that of controlled soft landing on an extraterrestrial body. Hughes Aircraft Company, the builders of the vehicle, and Jet Propulsion Laboratory, the program manager for NASA, had run into problems—of which simulating one-sixth earth gravity for experimental landings is a minor example—and the first Surveyor was not ready to fly. The AC-7 vehicle was delivered to the Cape, underwent a normal checkout and was ready to perform its mission, but when Surveyor proved unready Centaur program manage-

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ment decided to return the vehicle to Convair for updating by incorporation of many needed modifications. The schedule called for Centaurs 7, 10 and 11 to be single-burn configuration, and Centaurs 8, 9 and 12 to be two-burn vehicles. There was adequate time to fire one more R&D vehicle before the first Surveyor would be ready, and a decision was made to fire AC-8 and plan the first live Surveyor mission for AC-10.

When the AC-8 vehicle arrived at the Cape in January of 1966, ready for another two-burn attempt, it included a thoroughly modified Centaur. The problems encountered on the last two-burn attempt, AC-4, had been painstakingly analyzed, and corrections had been incorporated. The major trouble area was propellant management, with LH_2, of course, providing the more serious problems. AC-4 data analysis had revealed that severe disturbances were generated in the LH_2 tank at Centaur's first main engine shutdown. The small thrusters had performed their job of keeping Centaur under constant acceleration during the zero gravity coast period, but their thrust was insufficient to overcome these disturbances and settle the light liquid to the bottom of its tank.

The primary problem had been in finding the source of the disturbances, and the AC-4 flight had provided the answer. The Centaur designers had realized that LH_2 trapped in the fuel duct on the tank side of the engine pump inlet valve would vaporize at a fairly high rate during the Atlas burn. It was necessary, though, that *liquid* hydrogen be always present at the inlet valve, to keep the inflight pump cooldown period as short as possible when the time came to start. The method chosen to ensure this was a system of bleedoff tubes in the main ducts, and these conducted the gaseous hydrogen back to the main tank as it appeared. Intensive analysis of the AC-4 flight data revealed that engine cutoff and boostpump shutdown induced transient pressures in the fuel duct and bleedoff lines, pushing the gas out at high pressure. The returning gas from these recirculation lines was entering the tank with such velocity and volume that the main body of LH_2 was being kicked into motion, and the small thrusters were unable to settle it to the tank bottom. The random motion of LH_2 in the tank allowed some of the liquid to get into the pressure relief vent valve, resulting in the tumbling and loss of control experienced by the AC-4.

With boosters, sustainer and small vernier engines firing brilliantly AC-6 lifts off the pad. Note gaseous hydrogen trailing from vent fin on nose fairing. AC-6 was the first vehicle to carry a Surveyor mass model on a successful "paper moon" mission.

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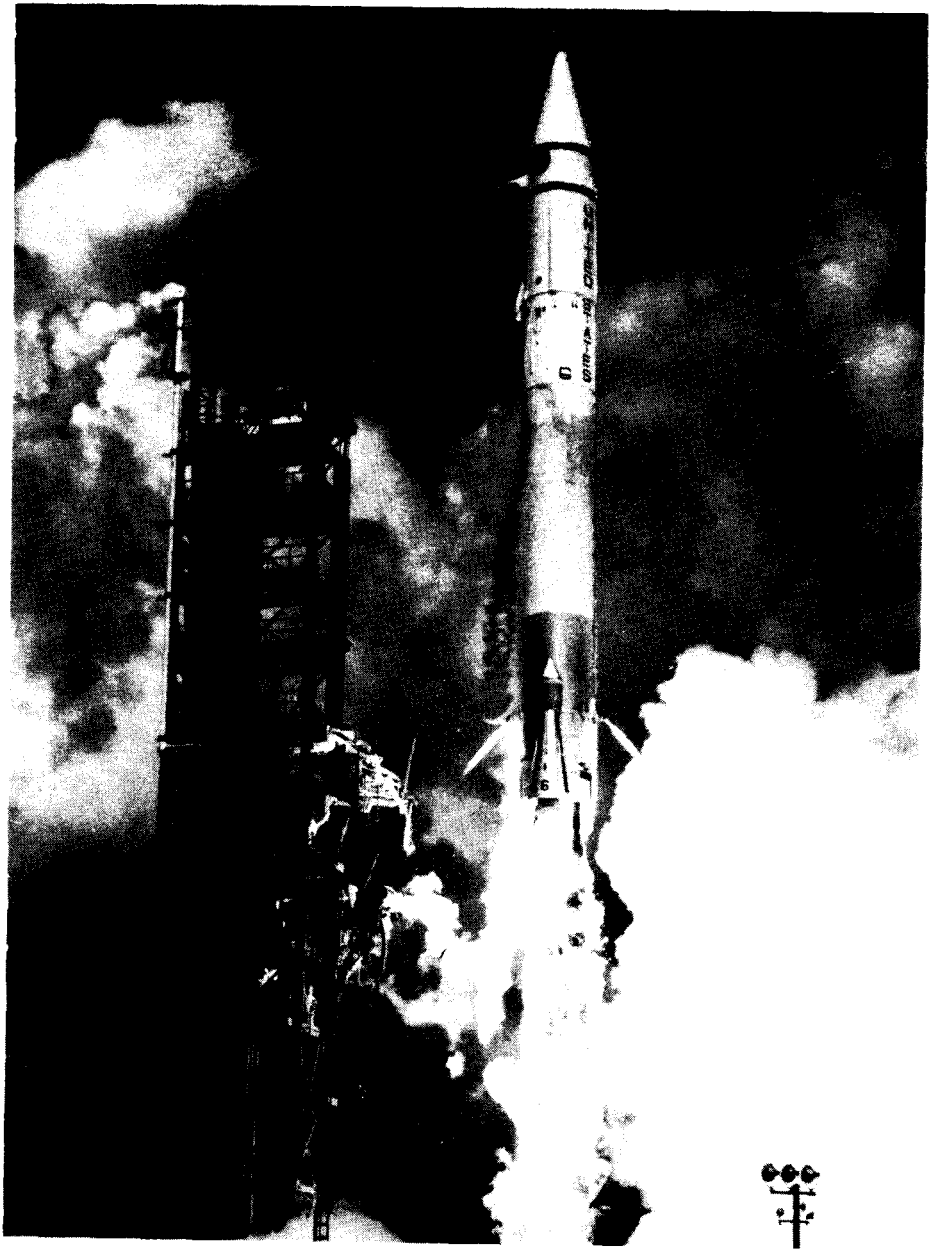

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The problem was approached from more than one angle. Slosh baffles were installed in the LH_2 tank to reduce the magnitude of the disturbances, and energy-reducing diffusers were installed on the ducts returning the bleedoff gas back to the tank. These were simple but highly effective solutions to that particular problem. The difficult part, as usual, had been in pinpointing the trouble.

The vent valve was thoroughly reworked, including a relocation on the LH_2 tank and the addition of a "torus tube" design piping system connecting the primary and secondary vent valve outlets. This included two diametrically opposed vent openings in the torus, with a carefully calibrated orifice in each. The connections to the nose fairing vent had to be completely redesigned, with separate breakaway points on each side of the torus to permit nose fairing jettison. The final design was considered incapable of imparting a torque to the vehicle under even the most adverse circumstances.

The last approach was to strengthen the H_2O_2 system, both in the attitude control system and the settlement engines. The thrust of the yaw and pitch control jets was doubled, to give the vehicle far more self-correction capability. Four three-pound thrusters were installed, to fire for the entire length of the coast period. To be certain the liquids would remain at the bottom of their tanks after the transient forces experienced at engine shutdown, and to make sure they were completely stable prior to second engine start, four fifty-pound thrusters were installed, and programmed to fire during both operations. It appeared that every problem had been anticipated, and seemed virtually impossible for anything to go wrong in this area.

AC-8 also incorporated a new and improved form of the P&W RL10 engine, in prototype form. It was called the YRL10A3-3, and had an increased nozzle expansion ratio, increased chamber pressure, and an improved injector design. These improvements combined to give an eleven-second increase in Isp, from 433 for the -1 engine to 444 for the -3.

After several false starts and delays due to weather AC-8 lifted off from pad B on April 7, 1966, carrying another Surveyor mass model. Lift-off, Atlas burn and Centaur first burn were normal. When Centaur entered its coast phase the redesigned propellant and attitude-control systems worked perfectly, the propellants remaining at the bottom of their tanks and the vehicle retaining the correct attitude throughout the coast period. But a new trouble appeared while the Centaur was performing so well, a small H_2O_2 leak in one of the new three-pound coast phase thrusters. The monopropellant drained steadily into space, and after twenty-five

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minutes of coast the supply was almost depleted. The four fifty-pound thrusters came back on, followed shortly by an attempted second engine start, but there was not enough H_2O_2 available to power the two tank boost pumps. A normal engine start could not occur, though both engines did ignite when the start sequence was completed, and one climbed to near full thrust for a few brief seconds. That short unbalanced thrust was enough to send the vehicle tumbling out of control, and it was lost. But an important point had been proven. LH_2, despite all its tricky unknowns, could be controlled, and hydrogen engines could be restarted in orbit. Some of the bugs were beginning to yie'd to continued pressure.

The first operational Surveyor arrived at the Cape on March 14, 1966, and AC-10 was ready for Centaur's first true mission. Vehicle and spacecraft went through the complicated checkout procedures with a minimum of trouble, and AC-10 lifted off on Memorial Day, May 30, 1966. The story of that launch has been covered elsewhere (see Analog, March, 1967). The unexpected and overwhelming success of the Surveyor on its first mission brought it worldwide acclaim. The fine performance of the Centaur in injecting the spacecraft into its lunar trajectory so precisely that it would have hit the moon near the target area even without the programmed midcourse correction was generally overlooked. The people who had been struggling with LH_2 and its first application in the Centaur program knew what they had accomplished, and were content to let the spotlight settle on Surveyor. Besides, they still had to solve that nagging problem of a successful second burn.

The needed factory modifications had been incorporated in the AC-7 Centaur while 10 was on the pad, and it was ready to fly. It was provided with a new Atlas booster and returned to the Cape, programmed to send the second Surveyor after its sensational predecessor. After a smooth countdown AC-7 lifted off on September 20, 1966. The updated vehicle was virtually identical to Centaur 10, and performed in an identical manner. The Surveyor was also identical, but a weakness, which had not been apparent on the first spacecraft, manifested itself when the vernier engines were fired for the standard midcourse correction. One of the three engines failed to ignite, throwing the Surveyor into a spin, and repeated attempts to fire all three verniers—which could not be started separately—had the same result and increased the rate of spin. JPL finally ignited the main solid fuel retrorocket; the sudden application of a large thrust in a straight line opposed the centrifugal and centripetal forces generated by the spinning, and the craft disintegrated.

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The Centaur crew had no time to waste crying about Surveyor 2. Surveyor 1 had performed so well the program could withstand one failure, and they had their hands full with AC-9. The vehicle had been erected on pad 36 B long before AC-7 lifted off, and the crew had been carrying out two simultaneous checkouts. The pressure was on to prove the two-burn capability of Centaur, and that was the primary test objective of this bird. The next two-burn vehicle, AC-12, was already programmed to carry a live Surveyor, and would be the next shot. The engineers were certain they had solved every problem associated with a second burn . . . but they had been certain before, and been wrong. The only acceptable proof was a completely successful flight, one that met every objective. AC-9 was expected to do this, and thus be the final R&D flight in the Atlas-Centaur launch vehicle development program. The mission was to boost another mass model Surveyor into a simulated lunar transfer trajectory.

The H_2O_2 leak which had marred the AC-8 flight had been eliminated, everyone hoped, by a redesign of the coast phase and attitude jets. A new type of welded construction had been incorporated, one guaranteed not to leak. In addition the entire system, from bottle to every individual nozzle, was meticulously checked and rechecked by the launch crew.

The improved P&W engines, again in prototype form—the production version was reserved for the upcoming AC-12 mission—had been installed on the Centaur, and they were also carefully prepared. A last-minute check on the delicate thrust controller was performed by P&W personnel, to be certain it was free from contamination which could stop up vital flow passages. AC-9 was checked out as thoroughly as the "dirtiest" bird that ever arrived at the Cape.

When the vehicle lifted off, on October 26, 1966, all the trouble and extra effort paid off. The Atlas sustainer engine shut down six seconds early, but Centaur automatically compensated by extending its first burn time by ten seconds. The parking orbit was achieved, and propellant control during the coast phase was perfect. Engine cooldown and second burn occurred exactly as programmed, hurling the Surveyor mass model toward its "paper moon" with a high degree of accuracy. The mission was listed as a resounding success, and Centaur was finally fully operational.

Some disquieting facts were visible behind the scenes, however. That Atlas sustainer engine early shut-down had apparently been caused by damage to an exposed line during the complicated booster staging operation. It might, or might not, happen again. Of more interest to the propulsion experts was an unexplainable decrease in

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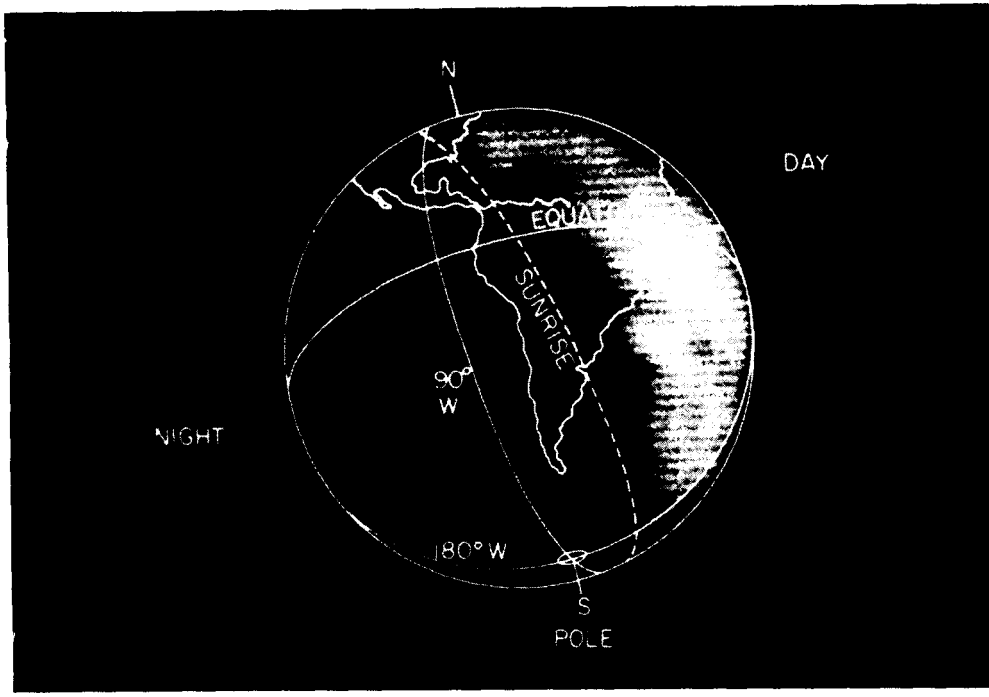

Photo of crescent earth taken by Surveyor 3 on moon, at 3:37 a.m. PST, April 30, 1967. Superimposed lines show outline of globe and continents. About four hours of daylight can be seen. Note tilt of earth and position of sunrise line.

performance by one of the P&W engines. Thrust from this engine was about 250 pounds low. This was a small percentage of the 15,000 pounds the engine was designed to produce, but the fact remained the drop should not exist.

Another new problem was that the H_2O_2 engines had done their job almost too well. Careful data analysis revealed that the superheated steam exhaust from their nozzles was impinging on the housings of the lox and LH_2 turbine pumps, causing a significant warming trend. The effect had been suspected on AC-8, and was now confirmed.

AC-9 went down in the books as a complete success, but seemed to have spawned a few new bugs whose future behavior could not be predicted. But the Surveyor program was on the move now, calling for a very ambitious launch schedule in 1967. AC-12 arrived at

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the Cape in February of 1967, and in two action-packed months all tests were completed and the Atlas engines roared to life on April 17th.

The Atlas flight was textbook perfect. The Centaur engines were the production version of the new RL10A3-3 improved performance type, and when the Atlas sustainer shut down they started perfectly. The first burn was normal, and all systems performed well during the long coast phase. Protective shields, which had been added at the last moment, guarded the lox and LH_2 turbine pumps from the steam exhaust of the H_2O_2 jets. Second burn was achieved correctly, and when the Centaur engines shut down again Surveyor 3 was on its way to a rendezvous with the moon.

The Surveyor spacecraft had been modified to prevent a recurrence of the previous flight's vernier engine failure. The changes were completely successful. Surveyor 3 performed its midcourse correction firing without difficulty, and went on to a rough but successful landing on the inner slope of a shallow crater 650 feet in diameter. Due to the tilt provided by this slope the spacecraft was able to focus its survey camera on the earth, an unprogrammed but welcome benefit. A full eclipse of the sun by the earth was photographed for the first time, providing a series of pictures that will keep astronomers busy for years. And photo coverage of the moon, the original primary mission, was comparable to that of its famous predecessor, though not as many shots were taken.

The attention of the world was caught by an item new on Surveyor 3, a tiny little extension scoop which had replaced the original lunar approach camera. This small, insignificant-looking instrument, on its lazy tongs extension arm and flat cable pullback, dug repeatedly into the lunar surface, and by measuring the power required to pull the scoop through the soil, and photographing the several trenches both during and after the digging operations, the question of the bearing strength of the lunar surface was answered once and for all . . . and favorably. Astronauts can land and walk without fear.

Proving out Centaur was a long and difficult job, but the vehicle is paying its way now, and will provide a high return on total investment before, like all good workhorses, it finally becomes obsolete. By the time this article sees print all seven Surveyors will have been

Surveyor 3's scoop moves toward footpad, on which it deposited soil sample. Impression at bottom left is positioning mark made by scoop; trench is out of sight to left. Circular impression above footpad is imprint made when Surveyor completed rough landing with all systems intact. Note color chart attached to leg, bottom center of footpad.

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launched, completing a program that will have brought scientists the most certain knowledge of the moon they are likely to obtain prior to a manned landing. In the second quarter of 1968 the second Orbiting Astronomical Observatory will be launched by the Atlas-Centaur combination. The first of the OAO's, a satellite program of great importance to astronomers, was launched in 1966 by the Atlas-Agena, but failed to function in orbit, and the redesigned satellite is now too heavy for any medium vehicle except Centaur. The present schedule also calls for an Applications Technology Satellite launch in the third quarter of 1968, to be followed by various other missions. In 1969 two Mariner Mars missions are programmed, and more OAO and ATS launches through 1971. New and larger television transmitters, possibly broadcasting directly to the individual home antennas, are as of now scheduled for the 1971-1972 period. The list of possible middleweight satellites is endless.

Another Centaur job being given serious consideration for the 1970-80 decade is that of deep space probe. A new version of Centaur, one featuring only one engine of 20,000 pounds thrust, is under study as the upper stage on a more powerful booster, such as the uprated Saturn 1, or Titan 3-C. Such a combination of large booster and long-burning Centaur would be capable of getting a sizable payload to Jupiter or Saturn, or taking a package of instruments out of the comparatively small disk in which all the planets orbit and exploring an area of our solar system which has seen little penetration. And the cost per vehicle would be only a fraction of that for a giant Saturn 5, the only other U.S. vehicle capable of similar feats.

Pound for pound the Centaur is already the most powerful rocket in the U.S. (and probably the world), but with all the advantages hydrogen offers as a fuel the liquid form still has the drawbacks of low density and high volatility. Some experimental work with slurry, a mixture of solid and liquid hydrogen, promises a large gain in efficiency in these two areas. Studies by the National Bureau of Standards indicate that large-scale production of slurry is feasible by the "freeze-thaw" method. If a vacuum is pulled on a liquid hydrogen dewar the temperature drops from evaporative cooling and a solid crust forms. A reduction in the vacuum breaks the crust's adherence to the walls and it settles to the bottom. The process can be repeated until a high percentage of the hydrogen is solidified, but this is not an optimum mixture. The solid particles formed in this manner are up to 3/16-inch long. If the particles are reduced in size by stirring or aging, and the solid content is established at fifty-five percent, the resultant slurry formed when liquid fills the spaces

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between particles occupies twelve point five percent less volume than liquid alone. A fifty-five percent solid mixture is also the maximum at which the solids disperse easily throughout the liquid, and the slurry flows readily without changing its composition. The decreased volatility of slurry results from its lower specific heat, which means a longer storage life in orbit and a reduction in loss by boiloff.

The advantages of replacing liquid hydrogen with slurry are obvious, but so are the problems. The solid particles must be kept in fairly uniform dispersion throughout the liquid, and at the magic fifty-five percent content figure, to prevent packing and flow blockage. A reliable means of continuously measuring the solid-liquid percentages must be found, since present methods are practical only within the controlled conditions of a laboratory. Design changes to the existing RL10A-3C engine pump would be required before it could handle the more dense slurry, and since the mixture is 12°F colder than liquid hydrogen the effect of this drop on all the delicate temperature balances in the Centaur would have to be determined. This would require a new Research & Development program on the bird. A preliminary study indicates that the cost of converting the Ground Support Equipment to slurry would be negligible, but a new experimental flight program on the Centaur would be very expensive indeed. At present the vehicle is meeting its program objectives too well to justify the expense. Advances in hydrogen technology are inevitable, however, and in the 1970's new launch vehicles will undoubtedly appear, with new and colder hydrogen bugs to tame.

That should end this report. AC-12 was an operational two-burn mission, and every objective was met at last . . . but the propulsion engineers had been busy analyzing flight data, and a newly hatched baby bug had started to grow. That low-thrust problem on one AC-9 engine was back, and this time on *both* engines! Flight chamber pressures had been considerably lower than those recorded when the engines went through their acceptance firings at P&W's West Palm Beach facility. The most likely suspect was the complicated thrust controller, which was supposed to sense chamber pressure and adjust turbine power as necessary to regulate propellant flow. Why had it apparently shifted downward in its power setting? The Centaur had had to burn fourteen seconds longer than programmed to compensate for this lower thrust, cutting much too deeply into the vehicle's performance margin.

The rocket engine experts at P&W, Lewis Research Center and Convair have unholstered their slide rules, and are once again advancing to do battle with this new strain of the persistent hydrogen bugs! ■

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There is a Tide

With every valued thing
there will be hordes
seeking to grab.
The best defense is to prove
they want it not.

R. C. FITZPATRICK
AND LEIGH RICHMOND
Illustrated by Kelly Freas

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In the days of Tammany Hall, Joe would have been a ward heeler. The reins of power having long since passed from political to other hands, he was something else. But the characteristics, abilities and information demanded of him were much the same. The rewards, too, were commensurate; the rewards, and the power behind the rewards that made possible the services he rendered.

Joe was the man who knew, by full name and antecedents, every person in the neighborhood; who was intimately acquainted with the state of each pocketbook, the status of each individual with the law. He knew who was employed, and at what; who was employable; who walked the streets; who was dependent on what medicine, alcohol, or dope, and where they were obtained; where the crap games could be found . . .

. . . And who could be depended on. If somebody could not be depended on, it was his job to know why, and to correct the matter.

There is such a Joe in almost every slum area in every city, large or small. Once they were minions of political machines. When the reins of power passed to the twilight organizations of an establishment-controlled underworld, the minions changed masters—not methods. The new methods of control entered the picture at higher levels. The Joes are near the bottom of the power structure.

Each slum has its Joe; each group of Joes has its Big Joe. The Big Joes have a Big Joe, at which level they, in turn, become Joe. There is no "bigger" or "biggest." The adjective "big" merely establishes peck order in any given relationship. At gatherings, the ranking Joe is Big Joe. By courtesy, at social gatherings, everybody is Joe. A distant Joe is referred to by location and relative position in respect to the area concerned—a reference, say, to "Chicago Joe," or "Chicago Big Joe." It is a purposely confusing system of nomenclature.

At the neighborhood level, obedience to the local Joe is not so much through fear as through dependence. What a Joe asks is regarded as probably good; he's always a good old guy. He watches and wards over them, pulls the strings that need pulling, worries about their finances, rescues them from troubles, rescues their sons from jails, coldly outsides the nonconformists; and is as comfortable as an old shoe.

When a neighborhood Joe wants a service, he gets it.

This time this Joe in this part of Brooklyn was only inquiring casually. He was one of the few who knew the name of the imbecile for whom he inquired.

"I ain't seen Harry in a spell," he said, seating himself comfortably on the steps of the brownstone front tenement, beside a miscellany

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of unshaven males and a sagging female who could have been thirty or ninety.

"He ain't been around for a spell," said the female, cackling. She was Harry's mother. "A man come and took him off to a place for kids that ain't right in the head. Said Harry would get took care of good there."

"Social worker?" Joe was puzzled. Social workers spent weeks and months inquiring when they took an interest in any of his people. If there had been inquiries, he should have heard of them.

"Yup. Leastways I kinda figgered he was. Who else would'a wanted a eight-year-old balmy?"

"How often'd he come first?"

"Nah. Not like that. He just come, said Harry was a special education case and needed special care. He knew where he could get it. Could he take 'im?" The female struggled her unspecialized garments more closely around her in the cold wind. " 'Sure,' sez I, 'He needs it. You take 'im.' "

"He didn't come around a bunch of times asking questions?"

"Nah. Just the oncet. He got Harry. And he didn't come back."

Joe was upset. Things weren't routine in this. Something didn't fit. Social workers did not do it that way.

He worried the matter a bit. Harry was not a loss to the neighborhood—the local idiot. Strong as an ox for a kid his age; wrong in the head. He could have done anything, if you could get his attention long enough to get him to do it. Useless, because you couldn't. There was no attention there to get.

It wasn't something that should really worry Joe, though. Harry wasn't anything that could ever pay back to the boss; and it wasn't his job to worry about what didn't pay back to the boss.

But the qualities that made Joe a natural for the job of keeping track of the comings and goings and ways and means of the neighborhood were the qualities that made him worry at the problem of Harry.

If a social worker had him—well who cared? So nobody liked social workers, but Harry was a problem; and they oughta took care of the problem. That was what they were for, wasn't it?

Still, social workers should act like social workers. They had notebooks and papers, and they didn't do anything without they spent months making out papers and inspecting the premises, which made everybody nervous and guilty. Just as well this one hadn't.

But—it was different, and that made him restless.

"You sign papers?" he asked.

"Yeah. You always gotta sign papers. I can't write, but I made my X, and Jim there put his X beside it, and the man writ out our names beside and witnessed 'em. Then we all went up to the drugstore, and old Doc, he witnessed 'em, too."

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"What'd the papers say? He tell you?"

"He started to read 'em to us, but I couldn't figger what the words meant. He said it just meant we guv him Harry to keep care of, and that he promised Harry'd get good care. Doc, he tried to read 'em, but he got bogged down, and he had customers he had to tend, and then he said Harry'd probably get better care at this Sunnyvale place than with us, at that. And he signed. He asked the man, were they kind to kids there, and the man said very kind, that's what they were for. Special education of the in . . . in . . . in-ed-ucable, he said."

Well, Harry was gone and taken care of, and that was a problem off his shoulders for sooner or later with that ox-baby power of his he'd have gotten in trouble with the law. And Joe should have relaxed and forgotten it.

But he didn't.

Finally, he had to unload the problem somewhere. It irked. Always there, and he was always comparing it to the normal run of events, and it just wouldn't fit in the back of his thinking.

So he got up his courage and went over to Big Joe's bar, and he waited, telling the bartender he'd just wait till Big Joe came in, in the back booth.

In about an hour Big Joe came in, his cigar clipped in his lips and feeling a bit surly because it was early yet; and Joe spoke his piece.

"Whatta ya worryin' up a storm about a moron for?" Big Joe asked.

" 'M not worryin' about Harry, Joe. It's just that . . . it don't fit, see? This guy comes, no fanfare, no papers 'cept for one for them to sign. No investigation. No nuthin'. It just don't seem natural."

"Well . . . hell . . . you gotta problem offa yer shirt front. Ya oughta be thankin' your stars."

"Yeah. But Joe? Supposin' this is a racket, see? Supposin' they're usin' kids like Harry for . . . well, for experiments or sumpin', see?"

"Yeah." Big Joe puffed on his cigar, found it unlit, lit it carefully, and puffed again. "Yeah. Could be a racket at that. And if it's a racket, Big Joe's gonna wanta hear about it."

"Yeah. Yeah, Joe. That's what I thought. Maybe you could . . . ?"

"Yeah. Don't worry, Joe. I'll get it to him. Let you know." Big Joe slid from the booth, and Joe, heaving a sigh of relief, at last found himself able to forget the problem. Or at least to dispense with it in his worrying.

But not for long. The three, when they arrived at his two-room apartment in their chesterfields and bowlers and cigars stuck in their mouths, were a fearsome sight. They'd knocked all right, but they'd come right on in after the knock without waiting to be answered.

The look of them scared the daylights out of Joe.

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"We're from Big Joe," they said, and took seats, one on the chair by the table where he ate; one in the easy chair; one on the couch-bed.

"About this balmy, Big Joe wants to know what the man looked like that took him. And what kind of car was he driving. And did you get the license number?"

"I wasn't even there," said Joe, belligerent because he was afraid. "I'll take you over."

By the time the three had finished questioning everybody that had seen anything, they had quite a fund of information, and Joe had decided that they put the social workers to shame, though they didn't write any of it down. No notebooks. Still, something about the questioning filled a need in Joe, and now he *could* forget the problem. The questions might not have been asked in the normal manner, but they'd been asked, and the routine of life had been fulfilled.

The final act of the problem, nearly six months later, satisfied whatever itch was left in Joe. A lawyer arrived, also in chesterfield and bowler, cigar in his mouth. "I'm from Big Joe," he said. "Got a batch of papers for the parents of that moron to sign," he said.

Joe superintended the signing and there were lots of papers to sign. He witnessed the signatures himself. So that was as it should be. A follow-up.

Joe wasn't curious about results. He never had been. That wasn't his job, and it didn't pay to get curious.

It was only something that didn't fit the regular pattern that itched at him; and that itch had been amply scratched by the pseudo-following of the same pattern.

Frederic Sklodowska, Ph.D., leaned heavily on the railing as he let himself down the stairs. He was gaunt, aesthetic; a tinge of its former red still shaded his graying hair; his hawk nose seemed to precede his nearly-emaciated body down the steps. As he descended, his eyes focused with a slight grimace of annoyance on the figure waiting patiently for him to reach the bottom.

Arriving, he paused, one hand still on the railing, the other clutching an unkempt pile of papers against his jacket.

"Yes?" he asked.

"I'm Philip Evans, formerly of International News Alliance, Dr. Sklodowska. I still do occasional columns for them. I wonder if I might talk with you?"

"It's rather late. I've just finished a lecture . . ."

"I know. I was present, and I plan to use it in a column for this Sunday. I was hoping you'd have a glass of beer with me?"

Frederic Sklodowska waited a moment while the pain in his left side quieted and smoothed. No. It wasn't going to be a bad one this time. The twinge seemed to have played itself out.

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"Very well. Evans? Where did you have in mind?"

The place Phil had picked was nearby and quiet. A paneled room with a dark mahogany atmosphere, and a bar that spoke of the spittoons that had once graced the place. He and his guest settled themselves in a booth that was more commodious than most, and he watched while the physicist tamped his papers into an orderly pile; as he settled himself into the seat, leaned back, and finally let his gaze come to rest on his host.

"Would you like beer or something stronger?" Phil asked.

"Beer. Preferably draft."

Phil ordered, letting the warmth of their surroundings and the minuscule motions his guest was making ease the tension.

When the beer had arrived and the silence had become a mutual relaxation, Phil began to talk.

"I have been very much interested in your theories of time, Doctor," he said. "The fact that time has three dimensions, just as space has. Space has up, down and depth; time—past, present and future. It sounds as though you were almost predicating the possibility of time travel."

Frederic Sklodowska laughed. A relaxed laugh, Evans noted. The place was having its effect. "I'll leave time travel to the science-fictioneers," he said. "No. But actually, that depends on your definition of time travel.

"The mental self, of course, occupies that segment of time known as the present. The physical self occupies that segment of space known as 'here.' I am not implying that the two are necessarily separable, but I am implying that the concept 'time' is a mental concept and that the concept 'space' is a physical one. Which does not imply that either are not both, if you follow me.

"Now the physical self is concerned with the physical realities of 'here.' For instance, you here know that there is presumably an office, elsewhere, to which you will go and a typewriter on which you will type out what you decide to write about what I say. But the things that you can handle physically are the beer mug before you; and the air that you can breathe is the air around you. You are concerned, physically, with the things that are here.

"But, mentally, you can be concerned with the words that you will physically type out in the future when you get there. So that, mentally, you are visiting the future. You are also utilizing, as part of that concern, the ideas you gleaned from the words that I spoke at the lectern, which is in the past. You, therefore, are now actively, mentally, handling factors of the past, the present, and the future. Is that not so? You are operating mentally in the three dimensions of time. Yes?"

"Yes," said Philip Evans, intensely interested, forgetting for the mo-

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ment the real purpose for which he had arranged this chat.

"Now, physically, if I may make that distinction, you are limited to breathing the air that is within this place, to handling the objects within this place; and to carrying on the functions of the body concomitant with the space around it. But that space is three-dimensional; so that physically you are handling the three dimensions of space; while mentally you are handling the three dimensions of time. Skoal," he added, raising his beer.

"But the three dimensions of space that I am handling, as you say," Phil grinned, "are limited to this area, which is a very small part of the infinity of three-dimensional space. Thus, skoal!"

"And," replied the other quietly, "the three dimensions of time that you are handling are quite as thoroughly limited in respect to the infinity of three-dimensional time. You are handling remarks made less than an hour ago; with reference probably to ideas incurred—though not consciously being recalled—during your comparatively short lifetime; and you are planning what you will write within a fairly short segment of the future."

"Those words will inevitably change before I put them down, though. Whereas the space of this room will predictably remain the same."

"On the contrary. Both the space of this room and the aspects of the future are changing within relatively set limits. Barring catastrophic change in either. You may, you probably will, change the positioning of the words that you will write, but not their alphabetical form. You may not even write the words, but you will not change the patterns of living which are the parameters of your time changes—barring major re-patterning.

"So with the space of this room. Barring a major catastrophe, its walls will retain their present positioning, although their atomic and subatomic structure is constantly changing. The atmosphere of this room, to which your lungs have adjusted their various functions, is changing constantly, so that your physical self must change its functioning to meet the micro-changes in the oxygen and nitrogen—and nicotinic," he smiled briefly, "atmosphere around it as it goes. Three-dimensional space changes continually, you know, for all its apparency of stability. If you consider the atomic and subatomic changes, as well as the molecular changes, you have a movement far too rapid for you to keep in step with mentally. Your body itself is only able to follow the gross movements of the gross components of space.

"May I say that the changes in space are at least as complete and as varied as the changes in time as you pass from present to future? Can you predict the molecular com-

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position of the air you will breathe in five minutes any more exactly than the actions you will be taking in five minutes? If three more people enter the space of this room, the molecular composition of the air will be altered quite as drastically as the macromolecular positioning of the surrounding bodies; alterations at least as complete as those that will change the composition, though not the alphabetical structure, of the words that you may or may not write . . ."

"And where does all this lead you, Doctor?" Phil Evans's eyes were so intent that the other glanced up and was caught.

"Not . . . not very far, I'm afraid."

"But the research you have done could lead to rather spectacular findings?"

"I had hoped so. It looks so. Perhaps someone will follow the paths I have laid out. I am getting it all on paper in the most exact form possible . . ."

"Have you found an understudy?"

"No. I had hoped . . . but there does not seem to be anyone who sees these factors as I do and is willing to . . ." The physicist's voice trailed off.

"And you do not have the time left to finish the research yourself." Phil's voice was cruel.

The other looked up sharply. "What makes you say that? I have not told anyone . . ."

"I have made it my business to find out, Dr. Sklodowska."

"You, sir, are an extremely nosy, unwarranted . . ."

"I did not investigate for purposes of invading your privacy, Doctor."

"And just what do you call an invasion of privacy? Your profession . . ."

"Is notoriously inconsiderate. Yes. I am not."

"Then why . . . ?"

"Let me continue. The doctors have not found any means to . . . ameliorate the factors which give you a limited . . . a very limited . . . time span before you expect to die?"

The other shrugged. "We all die," he said. "That is part of . . . the future . . . in which my mentality ranges. It is quite fascinating to contemplate . . ."

"Would you change it if you could?"

"No one . . . leaves life . . . without regret," he said. "I . . . had hoped there would be time at least to follow this one part of my work nearer to its conclusions."

"Those conclusions should be quite important to . . . mankind? Wouldn't they, Doctor?"

"Are you attempting to unsettle me, Mr. Evans? I assure you I have been quite unsettled; and I find it . . . not amusing . . . to be taunted . . ."

"I am not taunting you purposelessly, Dr. Sklodowska. What I have

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to offer is dangerous. There is no guarantee . . ."

"Guarantee?" said Sklodowska. "I am a scientist, not a businessman. Do you offer something?"

"Something," said Evans.

Stephen Socrates Jensen, M.D., leaned back in his desk chair and passed a hand wearily over his eyes.

"I am a surgeon, Philip, not a magician," he said. "The man is already in his thirties, debilitated by a disease that will normally prove fatal . . ."

"Nonsense," said Philip Evans. "You're a magician and you know it and I know it and Helen knows it." He turned for corroboration to Helen Hinman, the gray-haired nurse who was quietly fixing coffee in the corner.

"Nonsense to you both," she said comfortably and unperturbed. "What you can do, Stephen, you can do. And what you can't, you must leave alone."

"The trouble is, there's a possibility that I can."

"And we can't afford to lose that possibility, Stephen," Evans's voice was almost pleading. "Frederic Sklodowska is on the verge of a mathematical . . ."

"Philip." It was the voice of the nurse quieting an obstreperous patient. "Stephen knows his limitations. He's . . ."

"If I fail, it's murder. No one may attempt . . ."

"If you refuse to try, it's murder —just as surely, though in more acceptable terms by the symbology of this civilization. Are you going to confine yourself to the terms of this civilization, Stephen? Are you going to accept those terms now, when you have refused to accept them before? Will you bow now when you have risked everything for which you stand by refusing to bow before?"

"Philip!" This time the nurse's voice was an order. "You are not to question . . ."

"Philip." The surgeon looked at the younger man, pacing off his impatience in quick strides across the office, his tiger-virility seeming ready to burst the confines of the small room; an animal vitality that refused to recognize the barriers imposed by his surroundings. "Philip. The decision is mine. The responsibility is mine. You may not question either."

Evans stopped in midstride. "I'll question both!" He looked from one to the other, then conceded. "Let me at least plead my case."

"No." This was the voice of the nurse, and it was adamant. "*Dr.* Jensen," the title was underlined, and used thus among themselves was an insult to the rashness of his impatience; was a return-to-godhood of the doctor by the nurse, as at a hospital bedside a nurse delivers complete authority into the hands of the physician over the head of the patient, and in defiance of any other world that may exist

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outside the patient's room. It was an assumption so old and so complete in its finality that mankind had for centuries handed over his responsibility for his own bodily decisions on hearing the tone.

Stephen Jensen, to whom the assumption was the norm of the authority that went with responsibility, hardly felt the mantle that was being replaced on his shoulders.

But to Evans the voice was an imposition of a right that was not warranted. "No!" he exploded. "Stephen can decide whether he will, or will not, take the chance. He cannot decide whether the chance should be taken. That decision is up to Sklodowska and only to Sklodowska."

The nurse looked at him in horror. This was not a side of Evans that she had seen before. And, though it was an argument her logic could recognize, it was one her training could not permit.

"Philip! You must not argue with . . ."

"I must. I need not argue with Stephen; but, if he will not hear, I must argue with you, myself, God if you like, or the devil. The decision to take, or not to take, the chance on the operation being fatal —that decision is Frederic's. The decision as to whether he, himself, will perform the operation is the only thing that is up to Stephen. However, since Stephen is the only one capable of performing the operation—the only person who will risk his skill and his reputation to defy the mores of a civilization that could not be persuaded if it knew—the question becomes a moot question. But the principle remains."

"We'll argue principle another time, Philip." Stephen Jensen relaxed. "I suppose a doctor normally gets the habit of considering himself the arbiter of the lives of his patients . . ."

Evans nodded mutely. He owed this man much. He respected this man completely. But the habit, ingrained in the medical fraternity, he thought, of assuming an authority —that was actually forced on them by the average patient—and accepting the position of being the arbiter of life and death . . .

Helen Hinman's voice broke the uncomfortable silence. "The only question before us at the moment is that of whether Stephen," her effort to bring the discussion back to civilized forms was evident in her accent of the first name, "will, or will not, perform this operation on this man, who is at an age and in a condition . . ."

Evans interrupted. "A man who is on the verge of stating accurately the relationship of space and time, not only as mathematical equations expressed in the fairy math of the purists, but in good sound usable everyday terms. Stephen, there is no possibility that Frederic can live beyond a few months . . ."

"Weeks, probably."

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". . . Beyond a few weeks as his body is now. Is the word 'murder' more essentially concerned with an act that destroys? Or with the withholding of the act that can save? There are, you know, 'The things that I have done and the things which I have left undone . . .' And which is the more positive? The action, or the refusal to act?"

"Philip, there is no doctor on earth who has not had to face this question; and as a fraternity we have made certain decisions with which I feel constrained to abide by . . ."

"As a fraternity, your brotherhood has made certain decisions which would outlaw you from the profession if your work were known."

"Not if it were known in its full context and understood. Of that factor I have convinced myself. I could let the medical fraternity know; and place before them the potentials so that they would understand. But in so doing I would also, inevitably, let the people know; and they would not understand."

"And your fraternity would, necessarily, be influenced and abide by the majority opinion of the people. In the case of your work to date, as in this case. No, Stephen, this decision is yours, not that of your blasted AMA."

Jensen stood up abruptly. "It is still a moot point," he said. "There is no body for the operation."

"And if there were a body?"

"There is no body. There can be no real decision in the absence of the possibility."

"And if I find a proper one?"

The doctor smiled crookedly. "Always before," he said softly, "we have had time. And your statistical percentages require that time to seek out. In this case, as in the others, all the factors must be met. And the period of time in which the patient is—operable—is, I should guess . . . and *this* is a guess, Stephen . . . is probably not more than six weeks."

From Joe to Big Joe to Big Joe to Big Joe and so, finally, to the Duke.

This was no amateur operation. The means for finding out what the Duke wanted to know were extensive; transcended the borders of nations, even of continents. And the Duke had decided that he wanted to know.

By the time he'd found out what the setup was—and even with his organization it took time—he had changed his thinking about what he wanted from that setup.

The hovercar that dropped into the meadow outside the fence at Sunnyvale held four men.

As Evans approached the four had already alighted. They were headed for the rambling building inside the fence—two ahead, in soft-brimmed dark hats; a large, rather shaggy, unhatted individual

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next; and then the duplicate of the two ahead bringing up the rear.

Evans had thrown on the sloppy guard jacket that gave him a chance to look over newcomers before they reached more important areas. He stood squarely in the path of the four, but the two in front barely slowed, brushing past him.

"Hold it, Joe." The big man's voice was deep, almost musical. The two who had brushed past stopped in midstride and turned. "You forgot your manners, Joe," said the big man softly. Then to the "guard": "You're Evans?"

Evans opened his mouth to reply, then closed it again.

"You're Evans," said the big man. "We came to see Doc Jensen. I expect you'll want to hear what we have to say. Never mind the act. Just take us to the Doc."

Evans looked the man up and down. Gray-haired, paunched but not obesely so; simply a quite heavy stomach. Wide-spaced gray eyes, a beefy but not unintelligent face. A mouth that was wide but very firm. And shoulders that looked like a bear's. The man was not young; but the vitality he must once have had was only somewhat attenuated. And he was not in the slightest perturbed by the careful scrutiny; was waiting quietly for it to be completed.

Evans, holding himself to a leisurely attitude, turned his attention to the other three. They might be triplets—identically dressed; narrow-eyed; pale, almost pasty-faced; each with a hand in a jacket pocket, a slight bulge at the armpit.

Strongarm guys, he thought unbelievingly, but he didn't allow the conclusion to reach his face. Bodyguard to this one? Yes, almost certainly.

"Leave your bodyguard here. You won't need them in Sunnyvale," he said abruptly. "I'll take you to Dr. Jensen."

The man shook his big head ponderously. "They come," he said briefly.

"Over my dead body." Phil Evans meant it. At least, he felt that he did.

"Nope." The big man smiled, a full-lipped smile that was neither forced nor casual. "No, son. They come, and you come, too. No dead bodies. And we're not about to hurt the Doc. You don't need to worry on that score. We want to put a proposition to him. We ain't got no intention of hurting him."

The "ain't" grated. The man was civilized—no, Evans corrected himself, the man was intelligent. Civilized was another concept. The "ain't" shouldn't have grated. But the voice was musical . . . which needn't mean a trained modulation, he reminded himself. Italian? Probably. And for a moment Evans had a picture of a gondola on a canal, a big man with tremendous shoulders poling—and singing.

He shook his head fiercely ridding himself of his fantasies. This was no careless Italian gondolier

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with a few *lire* in his pocket. The man's suit was hand-tailored, for all his shaggy appearance. The shagginess was in his face, his hair . . .

Carelessly, the big man waited for the other to finish his speculations, make his decision. It was a mind which knew the value of the uninterrupted time-lag, which recognized the need to let its quarry sense its danger and become afraid.

And, Evans realized, he had been given time to lose his resistance; for his instinctive stubbornness to evaporate: to decide to take the man on his own terms to the office he would have, seconds earlier, guarded at any cost.

He shrugged his shoulders. Round One to the big man, he thought, and turned to lead the way.

At the entrance to the building he paused. "Let me at least alert Dr. Jensen . . ."

"Nope. If he's not in his office, we'll wait—and you'll wait, too." The man was in command of the situation and was not prepared to let that command be questioned in any manner.

The odd group entered. The two goons—Evans liked that term better than bodyguard, it fitted them more aptly—directly behind him; probably, he thought, with pistols pointed at his midriff, and the thought made his ribs feel naked and exposed. Then came—the Boss. Then the third goon.

Evans reached Jensen's door, and raised his hand to knock, but the goons brushed past him, opened the door, placed themselves at vantage points inside.

Across the room Jensen looked up, startled. His eyes focused on the goons, then on Evans; then on the big man entering behind him, and the third—bodyguard.

He rose to his feet behind his desk, opened his mouth to speak, but the big man was standing before the desk now, leaning on it.

"My name's The Duke," he said. "Don't blame Evans, Doc. We came in spite of him. We want to talk to you, and we want to talk private, but Evans can stay."

He glanced behind to assure himself that the door was closed. It was, and the third goon stood before it.

Stephen Socrates Jensen closed his mouth with a snap, and remained standing, glaring at the Duke. Then he opened his mouth again and said carefully, "Your men may remain outside. You are in no danger here."

"That's as it may be. They stay. Sit down, Doc, because our conversation may take a while, and there's no need of your standing on your dignity. We got a business proposition to offer. It may take a bit to get across the idea, and we'll take all the time necessary. But there's no use your wearing yourself out putting on a front. That's for amateurs. You, too," he said to Evans.

Then he looked around, selected

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a comfortable seat near the doctor's desk, and leaned back.

Slowly Jensen sank into his chair and his gaze centered on the big man, analyzing him, cataloguing details, his eyes traveling over every inch of the heavyset figure.

The Duke was completely relaxed and silent. Giving him time, thought Evans admiringly, like he gave me time. This man is a genius in his use of time to his advantage.

The goons stood immobile, their similar pale faces almost featureless under the soft hats they had not removed; their lack of personality creating the effect of furniture, or rather of machines. They were simply equipment the big man might use if he cared to, so that in the conversation of humans they faded into the background of consciousness.

Slowly Evans walked over to the other easy chair in the office, sat down quietly, not disturbing the time that the other was granting so freely to Jensen.

The silence that hung over the room was, Evans realized, an absorbed silence, like the quiet of a quiet box. Outside the windows the voices of children playing in the big meadow made no dent in the quiet of the—box.

Finally, Jensen was finished. He reached out with his scrubbed surgeon's fingers and moved a box of cigarettes towards the other.

The Duke shook his head, but Evans reached in his own pocket, took out a cigarette and lit it.

"Well?" Stephen Jensen leaned back, waiting.

"It's like this, Doc." The musical voice contrasted again with the uncivilized phrasing, and Evans was amused again at the tiny shock the contrast gave him. "You're doing a job here. I can use a job like that. And I can pay for it."

"And just what is it that you . . . think—we're doing here?" Jensen's voice was colder than Evans had ever heard it.

The big man chuckled, deep down in his chest.

"Well," he said, "back in World War II, there was a sailor on a submarine. He got cut almost in half when a landing cable parted. You were a lieutenant then, Doc. A full lieutenant. You sewed him back together so good that after a while he was back on duty. That . . . I think . . . was the first time you used what you'd found how to do.

"It was about twelve years after that that one guy got his skull crushed, he was already dead, I understand, but just by minutes; and another in the same accident got his body crushed. You took the live head and the body of the guy with the crushed skull, and you sewed 'em together. It didn't work. Died. But you'd tried. But the Navy didn't see it your way. You'd decapitated a dying man, even if you were trying to save his life, and I reckon that's against regulations. Maybe they wanted to try you for murder. I don't know. Anyhow, they rail-

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roaded you outta the Navy and hushed it up real quiet.

"Then along come Evans here. His son was hurt in a football accident, and the kid was a basket case . . ."

To watch your son lie watching the ceiling; his mind bright, alert, idle; his body—completely useless. Evans was the bulldog type. He didn't give up when the doctors said, "Hopeless quadriplegic. If only . . ."

He found Stephen Jensen, and that surgeon said, instead, "If only another body . . ."

His son had a mind without a body. If only there were a body without a mind . . .

While the weeks passed, he watched his hopeless son, hoping. And while he watched he went over the factors, for there *were* nearly mindless bodies. But it couldn't be those. It couldn't be just a moron, or an imbecile. There was hope in those. It had to be a completely mindless body; one that didn't even know it existed.

And there were those, too, he found finally. They existed in sufficient quantities to make a statistic in the civilization; a tiny statistic, but a measurable one; and quite a stable one in any population. Three percent of a population, he found, fell below an I.Q. of eighty, and were classified in categories of imbecile, idiot, cretin, mongoloid . . . but still with an awareness of their own existence, and so inviolable.

But of that three percent, a fraction—three and one half percent of the original three percent—were hopelessly dependent, unaware either of existence around them or existence within. Vegetables, offering no response to environment or inward need.

And those could be used, if they could be found. It was a minute percentage of any population, but it equaled nine for each ten thousand. And in a nation of two hundred sixty million . . .

Evans began his search.

He did not recognize it as his life's work. Not then. He began as the hunter primeval, and the "meat" that he hunted was for his own family. Originally. But then, later, he hunted for the sons of others; because of his needs, he knew their needs; because of his suffering, he recognized their sufferings; his hopes, their hopes; his dreams, their dreams. It eventually became not a search, but a quest, and then not a quest, but a crusade.

He did not debate, then or ever, with himself or with others, about the rightness or the wrongness of his decision. He simply acted, and then debated whether there was a crying need for him to have taken action . . . or a terrible waste if he had not.

"The kids—the ones without minds, that end up here without

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very much body, though they never know the difference—you take good care of them. They're happy. You see to that." The Duke's voice brought Phil back to the doctor's office; back to the three goons fading so quietly into the background; back to the big man calmly telling Stephen and himself the details they had thought so secret . . .

"That kid, Tommy Magee. He's got a real fine body now; and he's got the brains to use it. And Harry Carmichael. He's happy. Never did know whether he had a body or not. Balmy kid. Probably still doesn't know. But he's out there," the big man chucked his thumb toward the window, "and happy as he's able to be, one way or the other.

"Now, Doc, I'm a religious man; but I don't hold with these priests who say you mustn't tamper with things as they are. Hell, man's been tampering with things as they are ever since he got put on the earth.

"And I like what you're doing. You've given a batch of kids something to live for; and the ones who didn't even know they was livin', well you haven't took anything was any use to 'em; and you've given 'em comfort and attention and as much happiness as they can feel—fair value in exchange. Yes. I approve of what you're doing, Doc."

"Then why are you—and I use the term advisedly—muscling in here?" Jensen's cold voice used its terms as precisely as the Duke's soft, musical voice did not.

"Doc," abruptly the Duke's voice was embarrassed, "I've got a brain. A good brain. You wouldn't approve of the way I've used it—lots of people wouldn't approve of the way you've used yours—but you gotta grant me the fact that I've gotta brain. Couldn't any addlepate build the organization I've built. And you've probably heard of it if I named it. And you've seen all the things about it you think are wrong. But the things that are right about it, and that make the little people love me and do what I say—those are the things you haven't heard. And I'm not about to tell you about them.

"All I'm trying to say is that I've got as good a brain as any kid out there that you've—operated on."

"I will grant you the fact of a good brain, Duke." Jensen's voice was soft this time, and Evans looked at him, startled.

"Not just a good brain, Doc. How many people you know could handle the organization I handle? It's . . . bigger than just even this nation, Doc, the organization. I'm the head."

"I'll grant you a really good brain, Duke." Jensen paused. "It is unfair to guess or to evaluate a man's I.Q. —but I should put you, I think, near the top of the genius class."

The Duke nodded solemnly, and Evans knew that he was pleased. "O.K., Doc. Fair enough. Now—I'm not young. And I can't afford to get any older. It don't pay in my

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business. Anyhow, I guess none of us wants to get any older. But I've got the money—and the means—to get what I want. To your advantage."

"I don't charge for my operations, Duke."

"I know you don't, Doc." Then the big man smiled suddenly. "Duke, Doc," he said. "Funny," he added and went on. "You don't charge—and you don't have an organization like I've got that can find what you want when you want it. And you don't have the money to do all you could be doing for the kids. And more important yet—you don't know how to protect yourself if you get into trouble, and you know, Doc, sooner or later it's going to catch up to you; and Senator Gilham"—both Evans and Jensen started at the name—"and the others won't be able to protect you. They won't even be able to protect themselves," he added.

"Granted," said Jensen softly.

"I can protect you, Doc. You can't be protected legal-like, but I can protect you, and you needn't even bother about how. That's my business, and I'm good at my business, and I know how to run it. I can protect you, Doc." He paused, and the other started to interrupt, but he held up his hand.

"There's another side to this, too, Doc," he continued. "I told you I like what you're doing, but I don't let my likes and dislikes get in my way, and you better listen to the other side of the picture before you tell me you don't like my kind of protection and don't want any part of it. The kids are worth my kind of protection, you know. But that's not all there is to it.

"I can unprotect you, too." He reached into a pocket and pulled out some papers. "Here's just one part of that other side," he said.

"That Magee kid that's got that nice, strong useful body now. Well, I know and you know that Harry Carmichael hasn't got no use for a good body; and that he's just as happy and just as well off like he is. But no court in the land would know that. And once it hit the headlines, nobody at all would know it. And you wouldn't be in business long, to give other bright kids good bodies. And Senator Gilham, he'd back you, but he wouldn't be there to back you because the least he'd get would be thirty years. You'd get the asylum for yourself, but he'd get thirty years. Evans'd get about thirty, too, I'd reckon.

"So you see, Doc. I got what it takes either way. And I want to do business."

"I wish you hadn't threatened me, Duke," Jensen said, his voice still soft. "I do wish you hadn't threatened me."

"I know," said the Duke. "You'd rather do it generous-like. But I like my generosity backed up. Now, I better tell you this, too. Joe, here," and he gestured to the three men . . .

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"Which one's Joe?" Jensen interrupted.

"They're all Joe. Just call 'em Joe," he said.

"I gather it's sort of a generic term." Evans couldn't keep from saying it; and unreasonably he felt himself about to laugh. There was nothing to laugh about, he told himself soberly; but the laugh was there, threatening to boil out in great guffaws if he so much as let up for an instant.

The Duke looked at him thoughtfully. "Generic," he said. "What's it mean?"

"Of the same basic family. Or rather, cut from similar genetic patterns," Evans explained.

The Duke grinned. "Yeah," he said. "Generic. Joe. They're all of a pattern. Anyhow, Joe—all of 'em that are my personal Joes—they know that if I don't come out right—they know what they gotta do. And the papers are all filled out and ready. The lawyer Joes are the brightest. They got that part ready. The others . . . well, they wouldn't like it if anything happened to me instead of what I told 'em was going to happen, and they'd probably take matters into their own hands. They're a little tetched," he said. "That's what makes 'em useful."

Evans glanced at the three immobile figures, but they didn't respond in any way except to keep their eyes focused on each move either he or Stephen made.

"Duke," said Jensen sternly, "will you please stop threatening me? I will make a decision irrespective of threats. However, it is possible that no decision will be required in this instance. The rules that nature has set up concerning the bodies that can be used, cannot be abrogated. The rules that we here at Sunnyvale have set up about those bodies *will* not be abrogated. And I have no such body for your usage. And the chances of finding a suitable one for you are far, far less than the statistical percentages on which we can hope to find them for children."

"Think I hadn't thought of that one, Doc? I know what your requirements are. I had them checked *real* careful."

"Then you know that the life expectancy of a truly mindless body is very low, and that most of them are dead before the age of puberty."

"Yeah. I found that out, too, Doc. But I haven't got the organization I have for nothing. Our business is to know people—everybody. Where they are, what they are, how to find 'em when we need 'em; what their financial and moral—and mental—condition is. I've got the guy, Doc. And he fits your specs."

"In your own age group? And just what good would that do you, Duke?"

"No, Doc. I got that one figgered, too. No. About thirty years, I figure you can take me back. Had to be a grown man, of course, I figured. He's thirty. Aren't many, Doc. You

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sure got the specs laid tight. Maybe there ain't but this one. But he fits; and he's available. I even got all the papers I could think of on him, including one from him, even though we had to make his mark by holding his hand and tracing it. He's trading what's useless to him for wealth and care and comfort. He may not know it, he doesn't even know he's alive. But he'll be happy and he'll be well cared for."

Jensen nodded, a smile, almost of self-satisfaction, ghosting his lips. "Yes," he said more to himself than to the others, "yes. That fits. That would be predictable." Then to the Duke, "I am a little surprised, though, at your efficiency in having the body ready in advance."

There was silence, then. That quiet-time again, thought Evans. Letting Stephen look at all the factors until he became thoroughly used to those factors. I.Q. genius? Evans didn't doubt it. The silence seemed to him interminable.

When Jenson's voice broke the stillness, Evans listened unbelieving. "Very well, Duke." His voice sounded a little sad.

"Stephen! No!" The words leaped out of Evans, and both the Duke and Jensen turned towards him, each with an expression of—patience?

"You . . . you *can't* let this . . . this *gangster* . . ."

"Philip." Jensen's voice was commanding. "We decided against supervising the results of my work; we decided that each child, given the new chance, should use it as he found best. Shall we grant less to a grown-up? We decided that the brain harbored the person . . ."

"But he's . . . he's had as good a chance as anyone! He wasn't born with a good brain and no body—nor maimed before he had a chance to learn! He's just getting old like anybody . . ."

"He has the disease of old age coming on, as your Dr. Sklodowska has the disease of . . ."

"But Frederic Sklodowska is a different question! He's just barely over thirty, and he's got a real contribution to make to mankind . . ."

"Philip. You spent several hours here convincing me that I could decide only the one question—whether or not I, myself, would perform the operation—under any given circumstances. I have made that decision."

Evans sat back stunned. Had he known Stephen Jensen so long and failed to find the weakness, the susceptibility to blackmail? The man who had gone on with his work because he believed in what he was doing at the risk of everything that he held important and dear?

But Jensen's voice was continuing.

"Do you drink, Duke?"

"Yeah. Wine, mostly. Pretty regular, I guess, but not drunk-drinking. Couldn't afford to."

"Marijuana?"

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"Naw. That's just for the stupes."

"Any of the dopes?"

"Naw. I use the dopies, not the dopes."

"What about the psychedelics?"

"The what?"

"LSD. The cactus derivatives."

"Oh. You mean trips. Nope. Like I said, I use the dopies, not the dope."

"Marijuana, LSD, the cactus derivatives—they're supposed to be nonaddictive."

"Yeah, Doc. That's the publicity. Maybe it's the fact. But in my business it pays to notice. And I've noticed that those that make that scene don't get back—those as use 'em don't quit, and don't come back to being bright again. I ain't hooked. Not by the . . . addictives or the nonaddictives." He used the doctor's terminology carefully.

"You would have to be here at the hospital for some time, for optimum results. Probably a month before and at least a month following any operation. And," he added wryly, "I should dislike to have your . . . Joes . . . misunderstand your long visit here."

"They won't misunderstand, Doc. But they won't misunderstand if I disappear, either."

"You realize that I cannot guarantee that an operation would be successful? There is a certain potential—especially at your age—that such an operation would be fatal?"

"We'll set it up so they don't misunderstand if it's fatal, Doc. We'll set it up real careful, because I don't want any misunderstandings here. Not when I'd be the goat. We can figure out the details. But I think I'll have a Joe watching all the time."

"As you wish. When are you prepared to move in?"

"I'm here, ain't I?"

"And how soon can you have the body brought here? I shall need time for tests—"

"Tomorrow O.K.?"

"Tomorrow. Yes. I will want to be sure that you have satisfied all legal and ethical requirements."

"Oh I have, Doc. He's been in a State institution for the past twenty-five years. They even have to feed him. But they've kept him in good condition. I've got legal papers on him."

"Very well. I'll check, of course. Now . . . will you want your Joes quartered in the same room? That would be crowded, but you might feel safer. Or would adjoining rooms be sufficient?"

The doctor's voice, to Evans's surprise, held no contempt; simply the consideration he would have shown a small boy in suggesting he keep his toy pistol under the pillow to protect him against the dangers of the dark. If the Duke recognized the attitude, he failed to show that recognition.

"I'll only need one of 'em for errands," he answered. "And a room next to mine's fine." Then he turned

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to the two Joes at the walls. "I'll phone every day," he said. "Usual code. Otherwise you two just stay at that motel in town."

The two seemed to come to life, slowly, but with an inevitability about their movements that fascinated Evans. How did they imply inevitability in a simple motion? The fact that the two pair of eyes unfocused from himself and Jensen almost as one gesture; that each seemed to slouch from an animal—no, a mechanical—alertness . . .

When they were gone, Jensen pushed the intercom. "Ask Mrs. Hinman to come to my office," he said; and when the gray-haired nurse appeared, "This is the Duke, Mrs. Hinman. He will be under observation for a month. He is not a bed patient, but I will give you a diet for him. No alcohol of any sort, Duke. And we will make tests beginning tomorrow. And this is Joe. Joe will have a room adjoining the Duke's."

Evans avoided Sunnyvale as much as he could; and he worked at the search for the complementary set of factors which would make it possible for Frederic Sklodowska to be considered.

But he could not avoid the sprawling, pleasant hospital with its chorus of happy children's voices completely, and when he did visit the place, he couldn't refuse to recognize the added vitality that seemed to inhabit it.

The Duke, he had to admit to himself, was a factor not to be sneezed at. During the long, pleasant days the big man could be found frequently out on the playgrounds, and the children gravitated to him. There'd be games in which he'd join occasionally, but mostly he'd just sit in the sun, and the children would be drawn to him, and pretty soon there'd be a group around him—one or two on his lap; others sitting at his feet with rapt faces while he told stories or simply let them talk to him, accepting their talk with the seriousness with which he'd have listened to an adult. Even the completely mindless Harry, who had warmed to the warm atmosphere of Sunnyvale like a flower responding to spring sunshine after a bleak winter, drifted with the others to the even warmer atmosphere around the Duke.

He listens so—so *hearingly*, Evans thought. And his vitality is sufficient to charge even the air around him. Why on earth does he want to have the operation? But he knew the answer. The vitality was spasmodic, and it wouldn't last. The man had a grip on life, and he was an intense egocentric. Children gravitate towards a true egocentric, he thought. Children—and adults, he admitted to himself.

Evenings the big man would sit around the fire, playing checkers with the slender scientist who had taken up residence there shortly after he had. "If we can do nothing

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else, we can be here to help you as it gets bad," Jensen had told him.

And Evans knew that Jensen would operate if the proper factors could be found. In this case, it was Frederic himself who was hesitant, but who had had to resign his work because of the increasing pain of his illness, and who had found the comfort and peace of Sunnyvale a refuge.

"I do not know that I could accept a body even from someone who had no knowledge of the fact that he possessed one; but since it can't be found, I shan't worry about it," Sklodowska explained to Evans. "I feel—unwarranted even in accepting the care that has been offered me here. The small amount that I am able to pay is no real recompense for what I receive. There is no amount that could pay, really, for the understanding and care that you offer me."

The two "patients" were about as unlike as two individuals could possibly be, yet they seemed to enjoy and to seek out each other's company. What is it that draws the egocentric and the exocentric so strongly together, Evans asked himself. The same factors, he decided, that make so many marriages between opposites successful. The same attraction that exists between opposite polarities throughout all nature.

The Duke seemed to have set himself to get the slender scientist to talking; talking about the nuances of his equations, which must be pure Greek to the man, Evans thought.

". . . The opposite potentials of space and time, each three-dimensional," Frederic was saying, relaxed in a comfortable chair drawn up before the fieldstone fireplace. "The existence of this continuum necessarily presupposes two forces of equal and opposite magnitude, interacting; an interaction at least as precise and as interdependent as that found in the electromagnetic spectrum, which is obviously the result, not the cause, of those forces. Let us name one of those forces space; the other time—using time in the sense of duration, not sequence. Then time will have characteristics of equal and opposite magnitude to those of space.

"Now, the body operates almost wholly in space, and can be shown to partake of the characteristics of space; and since the intelligence operates almost wholly in time, it can be assumed to partake of the characteristics of time. If this is so, then we can learn a great deal about each by studying the other. However, the relationship between space and time will be far less complex than that between the body and the intelligence."

"Judas priest," interrupted the Duke, "you talk about time as if it was a *thing*."

"It will quite possibly prove to be a *thing*, as the intelligence which

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shares its characteristics will prove to be a *thing*, though a more complex *thing*. For, in the evolutionary sequence, when you reach the body/intelligence configuration, you have, in the body, a high-order spatial complexity. Now we oppose that spatial complexity to an intelligence that operates almost wholly in time, the negative—the equal and opposite of the spatial configuration known as the body—and what do we find? A complexity at least as great, that can handle easily and daily such vector relationships as —say—hundreds of automobiles interweaving in intricate patterns and judge instantly the distances and speeds involved in bypassing one car with another against oncoming traffic . . . recognizing the future relationships involved in respect to the past factors of weight and maneuverability, and applying those vector analyses to present steering movements—yes, the intelligence operates almost wholly in time, and must necessarily partake of the characteristics of time.

"I could wish," he broke off suddenly, "that I might be around to study the results of the operation our good Dr. Jensen will perform on you, for I believe that much could be learned of the characteristics of the interdependence and interaction of the two forces of spatial and time configurations when the head and body are switched about in a mature man. But that, I am afraid," and he smiled cheerfully, "will be beyond my time—meaning sequence."

At Jensen's suggestion, Frederic was letting his beard grow, and it already curled softly about his chin and the sides of his face, retaining the wavy, red-brown texture his hair had lost at the onslaught of the disease which would inevitably prove fatal. His face was paler than it had been, and its long contours hollowed beneath his cheekbones. His slender fingers gestured gently and gracefully as he talked, seeming to have a life of their own.

He looks like an illustration of Christ, Evans thought.

The scientist had taught the gangster to play chess, and surprisingly, Evans learned, the Duke had proved a brilliant player, at least a match for the young physicist.

Maybe not so surprising, thought Evans. He's played his . . . well, I suppose you'd call it a career . . . with an astuteness few men could match; or rather, obviously, few men did match, for the games played by the Mafia, the Syndicate, the twilight organizations of which he must be top dog in one, set high stakes, and mastery is not an easy art.

In spite of himself, Evans found himself liking the man; but every time the liking began to come to the surface, he'd encounter Joe, and it would change again to the intensity of hatred that he'd felt at first.

Evans had decided to avoid Jen-

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sen, for he was truly torn by the man's decision which, he assured himself, he had no right to question. Stephen, he told himself, was a great man, a great doctor. If he had an Achilles heel—well, who hadn't? He seldom let himself even contemplate the factors of the forces that Jensen had refused to resist.

But as time wore on he realized that it was being too easy to avoid his friend; that he had barely caught a glimpse of him in any of his visits to Sunnyvale since the Duke had entered. Nor Helen either. Her duties would normally have her bustling around most of the time—but he'd not laid eyes on her, save once or twice in passing, for weeks.

Perhaps, he told himself sharply, they were both avoiding him as assiduously as he had been planning to avoid them. Fair enough. But as even the passing glimpses failed to materialize he became worried, and finally inquired.

"Dr. Jensen's been working so hard, recently, we're all worried about him," the nurse replied. "He and Mrs. Hinman, too. They're at the office at dawn, and they seldom leave before well past midnight. The doctor's looking tired," she added. "We're worried."

Several times Phil started to knock on the office door, to ask if he could be of some help, to try to mend the break that he himself had made between them; but each time his courage failed, and he turned away before knocking.

The weeks had passed, and Frederic's moments of uncontrollable pain were becoming more frequent. Jensen was ameliorating the pain as little as possible on the off-chance that . . .

And still the factors could not be met. And astonishingly it was the Duke, with his huge body and his musical voice who became the scientist's ally in pain. When the spasms hit, he'd be there, holding the slender figure by the arms, speaking low, encouraging words. And Frederic accepted the big man's ministrations as he could not accept them from others; as though his very strength made weakness legitimate.

Finally the day came when Jensen called Evans to his office, and asked the Duke to join them.

"Tomorrow," he said briefly, looking the big man deep in the eyes.

"O.K., Doc. Tomorrow." The Duke leaned back in his chair. There was a long silence between them.

Then, "You lost, Doc. You figgered I'd give over my chance to Frederic, didn't you? You even got him to grow a beard so he'd look like Christ."

Jensen looked startled. "Yes," he said. "Yes, I did."

The musical voice was fierce. "You don't get to where I've gotten, Doc, by being a softy. I've got maybe two years the way I am. Then somebody'll get me. You don't

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last long in my business, once you begin to fade."

"Sklodowska has maybe two weeks," said the doctor.

"I know, I know. And I could take that chance. But I'm not gonna. I've had my whole organization looking—and there's not another. Even if there were, it might not be as good a one."

"Very well," said Jensen. Evans remained quiet in his corner. There was nothing he could, or would, say.

"Well. Judas priest, Doc. It means life or death to either one, and a man doesn't give away his life for nuthin'."

"Judas priest?" said the doctor softly. "I thought it was Judas Iscariot."

The big man rose suddenly. "Don't try no more on me, Doc. I'm as good as my word, and you'll get the protection you need and have got to have to continue doing this stuff for kids. And that weighs in the balance too, y'know." He thrust his hands deep in his pockets. "I'll be ready tomorrow, whatever time you say."

"No food at all tonight," said the doctor tiredly. "I'll see you here in the office at six a.m. We'll operate . . . later."

When he was gone, Evans turned to Jensen. "You really hoped it would work, didn't you?" he asked bitterly.

Jensen didn't answer, and Evans tried to say something more, something to cross the gulf between him-

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self and the man who had given back life to his son, but the words choked before they reached his lips, and he turned and left.

It was three a.m. that the knock came on the doctor's door. It was three a.m., and a licked man who came into the room.

"You win, Doc," said the Duke. "You win. It wasn't the Christ part though, Doc. It's . . . I wish I'd had a son like him. He's . . . well . . . he's not yellow, you know. He's got guts and brains and . . . Hell, him and his time that's a *thing*. From anybody else I'd say they was balmy. From him . . . I dunno. He oughta be allowed to grow up and find out. There ain't no time for me, but I guess I just take the chance. I was just with him and he's . . . he hurts, Doc. Can you do it on him tomorrow?"

"Yes," said Stephen Jensen. "Yes, I can. I'd better."

It was almost noon before Jensen summoned both Evans and the Duke to his office, and when they came in he was pale and there were dark circles under his eyes. But there was a smile on his lips, and no gray behind the pallor. Helen Hinman, standing beside him, looked tired but happy, too.

"Did it work, Doc? Is Frederic going to be all right?" The Duke didn't even try to hide his worry.

The lips smiled slightly. "Yes, Duke. It worked. Frederic will be all right. Quite all right," he added. Then: "I've quite a bit to tell you, Duke, so sit down."

Quiet seemed to settle like a mantle over the big man's shoulders, and his face lost all expression. He walked slowly to the chair he'd occupied the first time he'd come to that office—only four weeks ago? Evans thought. It seemed forever. The man moved softly, easily, seating himself. Like a panther sensing trouble, Evans decided. There's something untamed about the Duke. His complete silence, the small motions he is using to occupy himself for the time he needs to . . . get himself under control? . . . are like a panther's switching tail.

Finally the Duke looked directly into the doctor's eyes. "Well, Doc?"

The doctor returned the big man's gaze as directly. "You think of yourself as a ruthless man," he said, "but you are too intelligent to be truly ruthless. It is true that you have little consideration or empathy for your inferiors; that you think of them and you treat them as some might think of or treat a rat or a snake. But you are vulnerable to your peers, Duke. For them you find consideration and empathy. You've never lived among your peers before; but you have now—and I could tell you to leave and do as you wished about your threats. You wouldn't carry them out."

"Don't be too sure, Doc," said the Duke softly.

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"Oh, I'm sure, but it doesn't matter, for you are not the problem. You are not the problem at all," he added almost to himself. Then the grim lips smiled almost gently, and he continued, "You thought you had to force us to perform the operation for you? I assure you that I would have gone to any extreme to be sure that you were here, available for the operation—if we needed you. I would have kept you here on any terms whatsoever.

"You see, you pointed out to me a vulnerability I had not realized existed. Oh, I don't mean the exposure you threatened, or the physical violence you implied. We had faced the probability of those before. If they can be avoided, we will avoid them; if not, they will happen. A man does not school himself to the ability to do, and do, what he knows to be right with the *exception* of those areas in which he will be punished for it; he does what he knows to be right because it is right, and takes full responsibility for the consequences.

"No. You showed me where I was truly vulnerable; not to you with your petty threats, but to those who would come after you. For them, I had to have an answer that would be final, absolute and irrevocable, under any circumstances whatsoever. I had to have that answer, Duke; and I would have had to use you to find that answer if I could not find it through lesser experiments. I'd have been quite ruthless about using you to get the answer, Duke, and I would have had not my peer, for you are, but because no alternate ethic could have justified me in not getting the answer at any price necessary."

Evans listened and watched in growing amazement. The man at the desk seemed to fill the room with a fury that was almost a physical blow, although the voice remained soft.

"Your threats were minor considerations, Duke, but they showed me what will—inevitably—happen." Then the voice took on a bleak coldness from which Evans found himself shrinking.

"You will be followed here," he said. "You will be followed by a vicious pack who can be barbaric in terms neither you nor I could match. You will be followed as surely as the thunder follows the lightning. And it is for that pack which will follow you that I had to have the answers. Since I know that any man can be broken, I know that I could be broken. I do not know how; and certainly *you* could not break me. But any man," he said almost to himself, "can be broken."

A sigh seemed to deflate him, then he straightened his shoulders again, and his voice became distant. "Have you thought what this world would be like if really vicious men could order the operation you ordered—and enforce that order? With the drugs that suppress the will, with chemical, physical or any

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other means necessary? They would have no scruples about 'specifications'—other than those imposed arbitrarily and irrevocably by nature itself."

"Yeah," said the Duke quietly. "Yeah. I thought of that. I was gonna protect you from that."

"You couldn't protect me, Duke. And I am not talking about what *might* happen. I am talking about what *would* happen. And, except at first, I would be used only to teach the less scrupulous the techniques; to teach the skillful who would be anxious to learn, instead of the medical fraternity which has refused, consistently, to look."

The distant voice paused, and the pause lengthened. And then the voice began again, and it held pain, but the fury was behind the pain. "At first it would be only the vicious, the truly barbarous. Then, on specious excuses, it would be found and demanded by the merely powerful or wealthy. But it would not be too long before the trade flourished to the point of bargain rates; and new-bodies-for-old would become fashionable; would make possible a new form of entrenched society, much as slaves made possible a form of entrenched society up to recent portions of man's history.

"And there would not be a vital, young body on the planet that would be safe. The more alive, the more vital, the less safe. The body markets would probably resemble the old slave markets—with an equal social acceptance, and an equal disregard for human values.

"So you can see, Duke, that I had to have the answer to your question."

He broke off. Then, in a voice weary to its depths, he said, "You see these rings?" He reached up and took Helen Hinman's right hand with his own, and turned them both so that identical cameo rings showed. Evans saw them through the tears that blurred his eyes. Neither one of the two, he thought, has ever worn jewelry—not of any sort—and these were large, almost cumbersome. He knew their purpose instinctively, but the tired voice was explaining. "It sounds . . . rather melodramatic, but—each of these contains a cyanide pill. A sufficient dose," he added.

Philip Evans felt his throat choking; felt a surge of anger at himself threaten to overwhelm him.

"That—and the papers in this office. It would have done no good to hide them or to burn them. That way our methods for handling the immune system which makes the operation possible would have been uncovered by other means. So we've spent the past month altering them, as subtly as we could. They lead now, very subtly, in false directions. It was the most that we could do. We hoped it would be enough—in case nature let us down."

The blood was surging through Evans's veins until he felt dizzy.

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Through the dizziness he heard himself saying, "But you're telling . . . this goon! You're telling . . ."

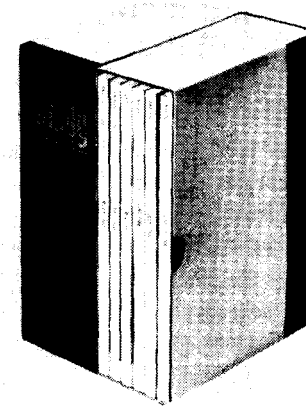
It was the Duke who answered him, his voice careful; his eyes hard.

"What the Doc's telling me, youngster, is that he's found his answer. That it can't be done. That he's safe. That it won't happen."

Stephen Socrates Jensen smiled with a smile that relaxed all the lines of tension under his dark-circled eyes. "Yes," he said. "Yes. I'm telling you that we have found the answer and that it is absolute and irrevocable." He slid the ring from his nurse's finger, then from his own, and laid the two carefully on the desk. "These are no longer necessary," he said withdrawing his fingers as if in distaste. "I assume I could still be forced to perform the operation. I could not be forced to perform it successfully, since nature has removed that responsibility from my shoulders. I, therefore, no longer need to be sure I could escape such force; nor Helen that she be sure she could escape telling what she knows of my methods."

Then he reached beneath his desk to bring up a cage with three rats: a baby, a lively young rat, and a bloated obesity lying on its side. Each rat had a tiny line of scar tissue about its neck.

The Duke looked at the three for a long minute. When he spoke his voice was scared. "That . . . that one's me, isn't it, Doc?" He pointed to the obesity.



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"Yes. That one was of your comparative age group."

"And that one's Frederic?"

"Yes. He had not yet reached full maturity when we induced cancer and let it reach the critical stage. Then we changed his body for a healthy one of the same age and type—but it's the age that makes the vital difference. Up to maturity, the physical brain retains the ability to adapt to a new environment—or a new body. But old age is the disease of self-immunity, and it is shared by the brain. Once old age has set in, once the body has reached full maturity, or just past it, the brain is no longer capable of adapting to a new body. It can't be done. So that the operation would be worse than fatal at any age when it would be desirable to the unscrupulous. Worse than fatal, because we would have to keep . . . this . . . alive if it were a man."

The Duke shuddered. Then he looked at the doctor in real fear. "You'd have done *that* to me if you hadn't been able to make sure of the answer any other way."

Stephen Jensen smiled gently. "I hoped," he said, "that it would not be necessary."

"But why," asked the Duke, and Evans could hear the bitterness in the man's voice through the roaring of the blood in his own ears, "why did you wait until I gave in about Frederic? Why did you wait until I broke and gave in? You must have known for days . . . these scars are healed . . ."

"Oh, Duke," said Helen Hinman, speaking for the first time, "we had the answer and we could *afford* to wait, you know. You had done us a favor in bringing this problem—somewhat forcibly—to our attention. And even if you hadn't," she added almost shyly, "you were with your peers at last; those who could respect you for the intelligence you possess. You *deserved* time to show yourself a man."

There was a silence so deep as to seem impenetrable.

"Anyhow," she added cheerfully, "a man who has just found his foster son needs time to adopt him. Frederic is going to need you, Duke. Any theoretical physicist needs—why, he's got to have!—a practical father."

The Duke's head came up, his eyes astonished. "Frederic—needs *me?*"

"Of course." The voice was that of the eternal nurse, always the go-between, enlightening the patient. "Of course he needs you. If nothing else, to see that he eats and sleeps and comes in out of the rain. He gets so busy thinking, he doesn't really know whether it's raining or not, mostly. And now, he'll be like a baby for a long time; almost a babe in arms, learning to use that new body. After that . . . well, shucks, I understand you have a big place out in the desert where he could work . . ." ■

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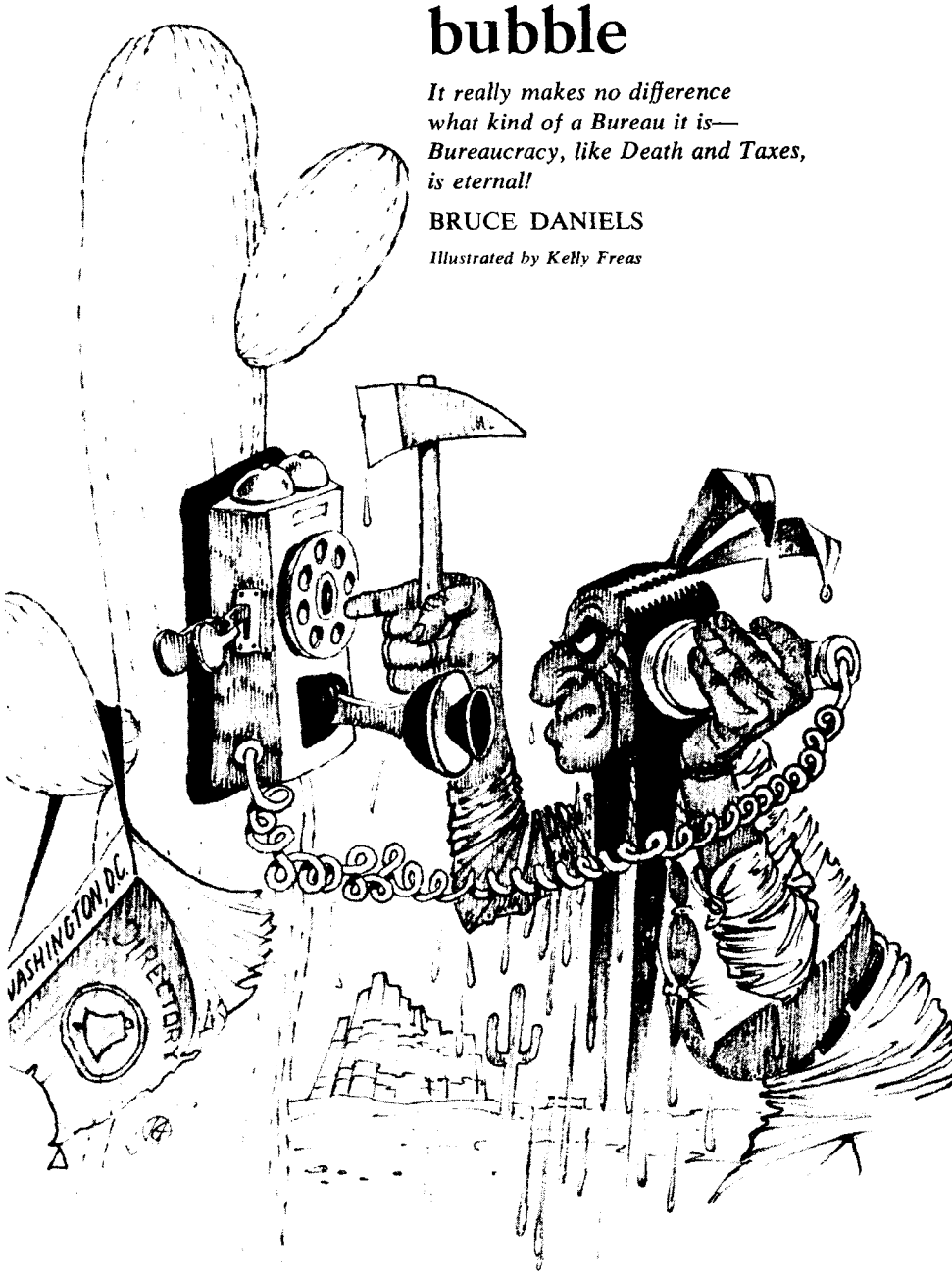
. . . AND CAULDRON

bubble

It really makes no difference what kind of a Bureau it is— Bureaucracy, like Death and Taxes, is eternal!

BRUCE DANIELS

Illustrated by Kelly Freas



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Cobs Butte, Montana
June 26, 1992

Bureau of Witchcraft
U.S. Department of Paranormal Affairs
Washington, D.C.

Dear Mr. Handley:

I saw you on the TV news last night, telling about the good things you people are doing for the country. Maybe you can help me. My farm is small, but it's all I got to live on. We never get much rain here in Cobs Butte, but this year's been the worst yet. Dry as a snake's tears for almost two months now. If we don't get some rain soon, I'm going to lose my whole crop for sure. Is there anything you witchcraft people can do to help me?

Sincerely yours,
Caleb B. Adams

ROUTE SLIP
7/1/92

From: Administrator Handley's Mail Room
To: Tom Noteworth
Special Assistant to the Administrator
For appropriate action.

ROUTE SLIP
7/10/92

From: Tom Noteworth
Special Assistant to the Administrator
To: Eric Strathmore
Special Assistant to the Special Assistant
Eric, better handle this one carefully. He may be from Congressman Trowel's district. I'm not suggesting we play favorites, but Congress has been making uncouth noises about our proposed budget for this year, and Congressman Trowel is the head of the Appropriations Committee.

Form Letter

Washington, D.C.
July 23, 1992

Caleb B. Adams
Cobs Butte, Montana

Dear Sir:

This is to acknowledge your recent communication, which has been referred to this office for action/reply. Please be advised we are taking the matter under consideration. You will be notified when final determination is made concerning your request.

The enclosed pamphlet, which explains the history and functions of the Bureau of Witchcraft, may be of interest to you.

Yours truly,
Eric Strathmore
Special Assistant to the Special Assistant to the Administrator

From earliest times, Man has been aware that some people have strange powers which were beyond his understanding or explanation. In more primitive times, these powers were ascribed to witches, demons, and pacts with various devils and unholy powers. With the coming of the late twentieth century,

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however. Man began to recognize them as what they are, natural but still poorly understood phenomena inherent to some individuals—a natural talent like perfect pitch or creativity.

Unfortunately, a deep-rooted and superstitious mistrust of these talents still remained in some of the less-educated segments of the population. As use of paranormal talents became more open and widespread during the 1980's, this medieval mistrust resulted in a series of nationwide disturbances popularly called the "ESP riots." In order to stop these disturbances and to regulate, study, and use for the common good these capricious, but natural, talents, the U.S. Department of Paranormal Affairs was established in 1989. The Department . . .

Dictaphone Notes to Secretary by Eric Strathmore

Maggie:

I had a bad night. Hold all calls this morning. (Never date a student of Historic Folkways. I'll bet she dragged me to every twist-a-go-go joint in Old Williamsburg.)

On the Caleb Adams thing: Let us bounce it over to Dowsing. They should be able to find water for the old goat.

Anything new on my request for promotion? It's been six weeks now, and my creditors are getting nervous.

By the way, Tom Noteworth says that if you don't stop mind-dropping on his private "conferences" with his secretary, he's going to fire both of us. I love you dearly, and your esper grapevine is invaluable, but knock off bugging the boss.

Oh, yes, call Harry Wythe in Records and see if he's free for lunch today. Maybe over the sea-dark wine I can find out something about my promotion. I don't want to stay Level G all my life.

ROUTE SLIP

7/28/92

From: Eric Strathmore
Special Assistant to the
Special Assistant
To: Hank Brownly
Division of Dowsing

Tom says this may be hot. Can your boys do anything to save the old geezer's crops? Where is Cobs Butte, anyway?

INTEROFFICE MEMO

August 3, 1992

From: Tom Noteworth
Special Assistant to the
Administrator
To: Eric Strathmore
Special Assistant to the
Special Assistant
Subject: Promotion

I talked to the boys from Personnel this morning. The outlook, I regret to inform you, Eric, is anything but cheerful.

I needn't remind you that I think you deserve your promotion and that I will do everything within my power to see that you get it. How-

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ever, you're also a big enough boy to realize that your fate is inexorably tied to mine. To the Personnel mind, you report to me and, therefore, must be my subordinate. They have "standards," and unfortunately the fact that we are two overworked, under-paid, downtrodden jerks doesn't cut any ice in the rule books. According to them we must show "significantly increased responsibility."

So there it stands. If you have any bright ideas on how we can significantly increase our responsibilities, speak by all means. You can get your Level F and I can get my Level E. Meantime, keep plugging!

ROUTE SLIP

8/11/92

From: Hank Brownly
Division of Dowsing
To: Eric Strathmore
Special Assistant to the
Special Assistant

Sorry, Eric. No can do. If there were any water reasonably available under the Adams farm, my crew could find it and pinpoint a well site for you. But even water-witching can't locate water where there ain't none. The water table is so low in that part of the country that drilling for agricultural purposes is economically infeasible. It's Gobi, son! What's he growing out there, anyhow?

By the way, in case you don't know it, Cobs Butte is smack in the middle of Congressman Trowel's home district. Appropriations. Have fun!

ROUTE SLIP

8/13/92

From: Eric Strathmore
Special Assistant to the
Special Assistant
To: William Biddle
Division of
Weather-Witching

Bill, I know how upset you people get about tinkering with your standard weather patterns. It plays hob with the year-end report and all that. But Dowsing says "no show" and this one's hot, baby. How about a little rain for Caleb? Just enough to keep Papa Trowel off our backs?

ROUTE SLIP

8/27/92

From: William Biddle
Division of
Weather-Witching
To: Eric Strathmore
Special Assistant to the
Special Assistant

Not for anyone else, Eric. As you said, it plays hob with the balance reports and makes picnic-goers across the country unhappy. But if you insist and since it's hot, anything for the taxpayer—and for the Appropriations Committee.

I can't do this on my own, however. Weather is a very interrelated commodity. We'll have to get clearance at least from the Weather Bureau, the Department of Agriculture, and the Department of Inte-

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rior. (Last time we made it rain somewhere, we upset a Hopi rain dance and had the Bureau of Indian Affairs down on our necks for six months.) Will you handle clearances?

Dictaphone Notes
by Eric Strathmore

Maggie, my love:

Hold all calls this morning, and try to scare up some bicarb. (Never date a woman who wants to prove what a good cook she is. I dined on *seaweed-burghers a la Cyano* garnished with algae and mutated chickpeas last night. Every time I belch I wither foliage for three blocks around.)

Try to set up a meeting on the Adams case for tomorrow afternoon. Talk to Agriculture and the Weather Bureau and see who else should be there.

Oh yes, remind me I have a 5:00 cocktail appointment with Saul Henderson of Clairvoyance. He got his Level F last month. Maybe I can pump him for some ideas.

Partial Transcript of Conference Held September 2, 1992

Strathmore (Paranormal Affairs): But damnit, we're not asking you to upset the whole continental weather pattern for the Northern Hemisphere! All we're asking is permission to make a little rain fall in Cobs Butte!

Conry (Weather Bureau): As we've told you, it isn't as easy as that. Tampering with the weather is tricky business at any time, and at this particular juncture it's exceptionally critical. You can't make it rain in Montana without making it not rain in Nebraska . . .

Hilth (Agriculture): And I daresay the Nebraska corn crop is more significant and just as badly in need of rain as Mr. Adams's crop.

Blute (Coast Guard): Not to mention the repercussions for shipping and small craft in our coastal waters. Why, with Hurricane Jocelyn sweeping toward the Gulf . . .

Yale (NASA): Or the Venus Probe that's scheduled for next month. If we have to recompute all the weather variables for the blastoff, it will delay us three days and cost millions.

Bergstrom (Federal Aviation Agency): Do you realize, Mr. Strathmore, what one minor change in weather patterns can mean for the entire complex of national and international airlines?

Willis (State): There, you've hit upon the crux of the situation, Mr. Bergstrom. International. Why with the crisis in Asia right now, not to mention the tenseness of the Arab-Israel dispute and Africa's current posture, we certainly cannot condone . . .

Jacobs (Fish and Wildlife Service): You must see, Mr. Strathmore, that the broad picture by far transcends Mr. Adams's imme-

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diate personal problem. I sympathize with your difficulty, but if your water affinitives can't handle it locally, I'm afraid you're out of luck. In this case, the mountain just can't go to Mohammed.

Dictaphone Notes
by Eric Strathmore

Maggie:

Go buy yourself a mink coat. Your boss is a genius.

I've been sitting here in the darkened shambles of my career, trying to figure out which of the monuments to throw myself off of, when something that was said at the conference today clicked. I think I've found my promotion.

Call Hank Brownly in Dowsing and tell him I've got to see him first thing in the morning. I'm going to bring the mountain to Mohammed!

INTEROFFICE MEMO

September 9, 1992

From: Eric Strathmore
Special Assistant to the Special Assistant

To: Tom Noteworth
Special Assistant to the Administrator

Subject: Potential New Use of Water Affinitives

Since the inception of the Bureau we have known that one of the least understood, but most dependable and consistent, of the many paranormal talents has been that of the so-called "water affinitives." Precognition, levitation, telekinesis may or may not work, depending on the conditions, the adept, or the time of day. But a skilled water affinitive almost always gets results.

Up to now we have utilized this talent only in a limited and passive way—using the attraction of the water on the affinitive to draw him to the water as in dowsing. It would seem logical, however, that this attraction must be reciprocal, and that, with application of sufficient talent, the water could be drawn to the affinitive or affinitives. (I have discussed this with Mr. Brownly, who assures me that such might be the case. Certain minor side effects of routine dowsing indicate that a latent reciprocity of attraction does exist, although the attraction has never been enough to have been considered significant until now.) By combining the skills of many affinitives in cooperative teams, therefore, it might be possible to control and even change the course of major rivers.

To adequately investigate the feasibility of such an action would be a lengthy and costly undertaking, calling for allocation of additional staff and budget support. (I would recommend the establishment of a special task force, headed at least by a Level F, to investigate the need and probable benefits of such a program.) The implications of such a program in national flood control alone would offset the costs, however, and would justify its signifi-

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cance as a major Federal program. Its possibility for controlling and changing the course of streams and waterways would have many additional applications. It might even be used in such matters as the Caleb Adams case to reroute a small stream to his farm.

If you agree, I propose we get the ball rolling by calling a preliminary study conference with other Federal agencies to determine possible applications in their program areas and to identify the probable limits of the study

INTEROFFICE MEMO

September 15, 1992

From: Tom Noteworth
Special Assistant to the Administrator

To: Eric Strathmore
Special Assistant to the Special Assistant

Subject: Proposed Task Force

Good show, Eric. Go ahead with the plans for your study conference. I talked to Administrator Handley about it this morning. We're scheduled to brief the Secretary of Paranormal Affairs on it tomorrow.

I have two minor comments on your proposal:

(1) I'd forget about such small applications as rerouting streams to water Adams's field. If we're going to put this over, we'll have to concentrate on the significant, national and international uses.

(2) I think you're underestimating the size and complexity of this project. I think the head of the task

The Analytical Laboratory

OCTOBER 1967

PLACE	TITLE	AUTHOR	POINTS
1.	Weyr Search	*Anne McCaffrey*	1.65
2.	Pontius Pirates	*J. T. McIntosh*	2.76
3.	The Judas Bug	*Carroll M. Capps*	3.02
4.	Free Vacation	*W. Macfarlane*	3.16
5.	Toys	*Tom Purdom*	4.20

THE EDITOR

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force should be at least a Level E—with a Level F assistant, of course.

Dictaphone Notes
by Eric Strathmore

Maggie:

Set up the conference. Include everybody who was at the first one. Better also include Army, Justice, AEC, Forest Service, National Park Service, and Coast and Geodetic Survey. And make sure State has someone from the Mexican Desk there.

Also tell Reisler in Public Information that I want to see him about getting some publicity rolling.

INTEROFFICE MEMO

December 8, 1992

From: Tom Noteworth
Chairman, Task Force on Water Affinity Reciprocity

To: Eric Strathmore

Subject: Reassignment

Congratulations! The attached papers officially notify you of your appointment as Special Assistant to the Task Force Chairman and promotion to Level F. We've a busy time ahead of us. If this thing works out, it may result in permanent establishment of a whole new division. We could even get another promotion out of it.

In answer to your question about what to do with the Adams case. Forget it. I need your full-time help right now on the task force. You'll have to leave any unfinished assignments for the new Special Assistant to the new Special Assistant to the Administrator to handle.

Cobs Butte, Montana
June 6, 1993

Bureau of Witchcraft
U.S. Department of Paranormal Affairs
Washington, D.C.

Dear Mr. Handley:

A year ago I wrote you asking help in getting some rain for my crops. I know you're a busy man, Mr. Handley, and I hate to bother you. But last year's harvest was so bad that I had to take a second mortgage on my farm to keep going. And this year promises to be even drier. I was wondering if you people have figured out anything that can be done in my case.

Sincerely yours,
Caleb B. Adams

ROUTE SLIP

6/20/93

From: Samuel Silverberg
Special Assistant to the Administrator

To: Lloyd Pressman
Special Assistant to the Special Assistant.

Better handle this one carefully. I'm not sure what the history on it is, but it could develop into a complaint.

By the way, Lloyd, I haven't forgotten about your request for promotion. I've set up a meeting with Personnel for next Friday. ■

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The System

Ben Bova

If you're going to have organization, you've got to have careful analysis, rules, procedures, and abide by them—

"Not just research," Gorman said, rocking smugly in his swivel chair. "*Organized* research."

Hopler, the cost-time analyst, nodded agreement.

"Organized," Gorman continued, "and carefully controlled—from above. The System—that's what gets results. Give the scientists their way and they'll spend you deaf, dumb, and blind on butterfly sex-ways or sub-subatomic particles. Damned nonsense."

Sitting on the front inch of the visitor's chair, Hopler asked meekly, "I'm afraid I don't see what this has to do . . ."

"With the analysis you turned in?" Gorman glanced at the ponderous file that was resting on a corner of his desk. "No, I suppose you don't know. You just chew through the numbers, don't you? Names, people, ideas . . . they don't enter into your work."

With an uncomfortable shrug, Hopler replied, "My job is econom-

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ic analysis. The System shouldn't be biased by personalities . . ."

"Of course not."

"But now that it's over, I would like to know . . . I mean, there've been rumors going through the Bureau."

"About the cure? They're true. The cure works. I don't know the details of it," Gorman said, waving a chubby hand. "Something to do with repressor molecules. Cancerous cells lack 'em. So the biochemists we've been supporting have found out how to attach repressors to the cancer cells. Stops 'em from growing. Controls the cancer. Cures the patient. Simple . . . now that we can do it."

"It . . . it's almost miraculous."

Gorman frowned. "What's miraculous about it? Why do people always connect good things with miracles? Why don't you think of cancer as a miracle, a black miracle?"

Hopler fluttered his hands as he fumbled for a reply.

"Never mind," Gorman snapped. "This analysis of yours. Shows the cure can be implemented on a nationwide basis. Not too expensive. Not too demanding of trained personnel that we don't have."

"I believe the cure could even be put into worldwide effect," Hopler said.

"The hell it can be!"

"What? I don't understand. My analysis . . ."

"Your analysis was one of many. The System has to look at all sides of the picture. That's how we beat heart disease, and stroke, and even highway deaths."

"And now cancer."

"No. Not cancer. Cancer stays. Demographic analysis knocked out all thoughts of using the cure. There aren't any other major killers around anymore. Stop cancer and we swamp ourselves with people. So the cure gets shelved."

For a stunned instant, Hopler was silent. Then, "But . . . I *need* the cure!"

Gorman nodded grimly. "So will I. The System predicts it." ■

Cover Available

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Such Stuff As Dreams...

The entrance exam for the mysterious Survey & Contact division didn't take long—but it was a dilly, and everlasting as Death if you flubbed it!

STERLING LANIER

Illustrated by Kelly Freas

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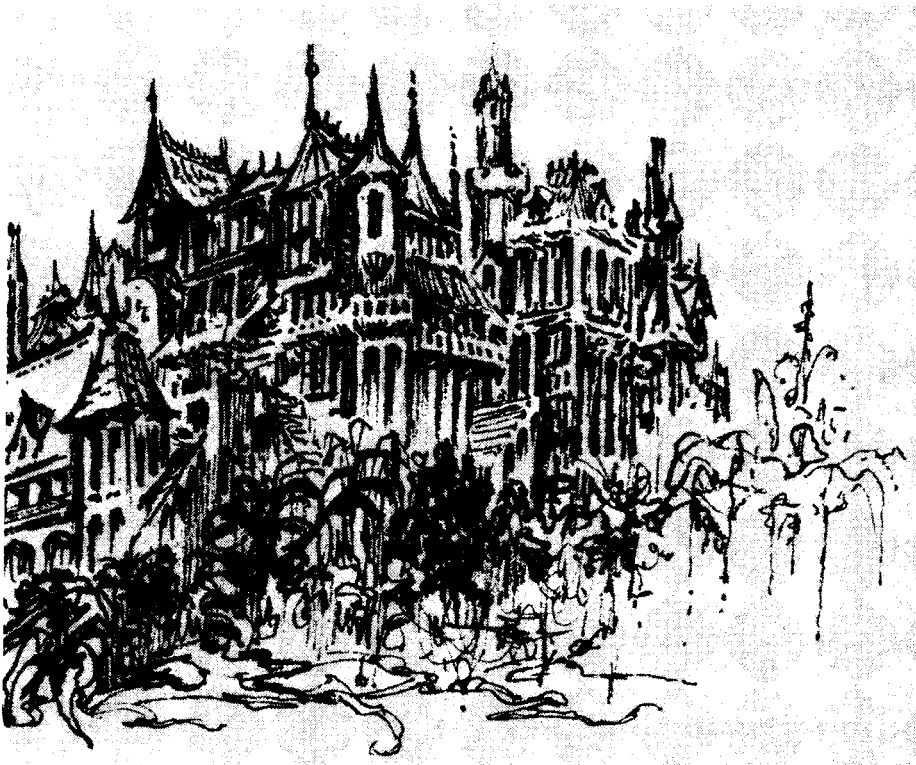

Commander William Jahangir Powers had reached a point where he was more than simply bored and annoyed.

He was neither a fool, nor a person who lived solely for physical action. He was a combat veteran with a distinguished service record and at the age of thirty-six, a very good officer indeed. His opinion of himself was only fair, but he had never felt outclassed by too many of his fellows. Now, however, he was feeling extremely angry.

He looked around for the fiftieth time. The room in which he sat was small and contained a plain desk and chair, a drab sofa and a monotone rug. He had come in the only door visible in the gray wall and now had been sitting for an hour on the sofa. Across the room behind the desk, sat a fat, stupid-looking woman of about fifty, with gray hair tied up in a bun and a mottled complexion. She had a figure like a lard can and wore a smocklike dress of olive green, ill-

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suited to her complexion. She might have been from Earth and might not. Humanoids capable of interbreeding with Terrans had been found four times elsewhere, possibly due to independent evolution. No one knew. In any event, this one was slowly writing something by hand on a pad, and had not even looked up when he had come in. She had grunted a few words, waved at the sofa, and continued writing, as she was still doing.

Powers stretched and yawned. His trim black-and-silver uniform felt sticky, and he was unpleasantly warm. The temperature must be at least 85° Farenheit in the small office, and he wondered where he was and grew thoughtful. Survey & Contact had a strange reputation among the regular services and did little by accident. He decided to mention it—the heat.

"Always this hot in here, Madam?"

An opaque, beady gaze lifted from the desk and focused on him. A nasal whine answered.

"Survey & Contact maintains perfect temperature control throughout Headquarters. We cannot be continually annoyed and questioned by visitors if any work is to be done." With that, the woman resumed her slow progress with the scriber, paying Powers no further attention.

Feeling silly at having spoken, he examined his wristchron—2:00 p.m., local time. He had been in the office almost two hours, waiting and doing nothing.

When the order to report to Survey & Contact Headquarters had appeared on his desk early that same morning, he had been processing some routine requests for equipment. The official summons was blunt and directed him to be at the entrance—which entrance was not stated—at 11:45 a.m. When he had finished reading it, he suddenly realized that it was already 10:00 a.m., local time, and also that he had no idea where on Sirius Prime Base the Survey front office was located. He examined the summons and found it had no directions on it and also no time or date of dispatch, which for an official document was unusual, to say the least. To add to his annoyance, as he stared at the thin sheet of buff paper, it began to dissolve before his astonished eyes. In two seconds a little dust was the only evidence that any such document had appeared on his desk!

All at once, the strange nature of Survey & Contact had again struck him. He had never met a Survey man or other being, and knew of no one else who had, either. All the rest of the services had an awesome respect for the branch, but no one seemed to know much about it. It was supposed to be open to any serving officer or enlisted man, but aside from the idea that it both contacted new races and func-

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tioned as a super intelligence net, little detail was really grasped by the rest of the galaxy. He could not remember when the idea of applying had first entered his mind, but the mystery was certainly in itself a factor.

Survey & Contact recruited humans and nonhumans as well. Everyone knew that a being capable of serving in Survey & Contact category was the absolute top, but it was still almost impossible to find out anything concrete about the corps. A veil of silence existed about its operations and makeup.

Intrigued and curious, Powers had patiently begun to amass a file of his findings about Survey, commencing the day he had first formally applied for entry, and a strange file it was. He had first transcribed every service rumor he had ever heard about Survey accomplishments, and then gone looking for more solid material. All his recent leaves had been spent in archives and dusty libraries. The interstellar newspaper files had been combed for any item, however fragmentary. And service files to which he had regular access were also scanned, as far as his rank would carry him without direct authorization from above.

The picture which had emerged made the strangeness of Survey & Contact both more interesting and more baffling than ever. Their personnel were paid triple service standard, for one thing! Secretive though the branch might be, this item had to be published in the annual appropriations of the Unified Services.

Public interest was obviously minimized and diverted by someone. News stories often said little more than that a new world had been visited or opened to trade by Survey & Contact. Gradually, as Powers' interest grew, he realized that entities, human and otherwise, of the Division must be located everywhere, all through the services and in civilian life as well. But the anonymity was fantastic.

Omnipresent, but invisible, Survey & Contact seemed to be all about, had a hand in everything, but was never seen or even acknowledged, except in the sparsest and least-revealing way. Further, Survey & Contact apparently seemed to have its own ships, bases and equipment. No one ever seemed to have seen any of these either, or at least would acknowledge it. A whole new world!

Within his own service, Powers had heard, on good authority, of at least three major crises in which battle fleets had been held ready. They were never needed. "S. & C. got in first" was the story in each case. The crises had simply evaporated and the fleets had then been taken off the standby list. Powers had friends in the regular intelligence outfits, but on questioning, they knew less than he.

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Powers' ultimate decision to join was based not only on what he had learned of the extraordinary work of the Mystery Division, but also on his own increasing boredom. A bachelor, with each increase in rank, his desk grew fuller and his planet-side duty longer. His personal initiative and drive seemed to him to grow lazier as well. At the time when the Survey legend began to grow upon his mind, he was actually thinking of leaving the Space Force and looking for a more exciting civilian career, if only to stop the walls of routine closing in. The less he could find out about Survey, the more attractive the idea had become, until finally it had assumed the force of nothing less than a compulsion.

His own application for the Division had been made over a Galac year earlier. Since then, he had continued his duties as a commander, Sirian Combine Space Force, without any real hint as to what had become of the request. But official forms had begun to appear on his desk at Sirius Prime, where he was serving a hitch at Grand Base Communications, and he had dutifully filled them out. They were mostly psychological questionnaires and almost all had been meaningless, at least to him. All had borne the magic title of Survey & Contact on their covers however, and so he had doggedly persisted.

One had ordered him to write an essay about the joys of dying of thirst! "Stress the appeal and pleasure of water deprivation," the form said. Another asked him how —in two thousand words or less— he would explain a new color to someone who had not seen it. Still another stated that he must imagine he was the survivor of an aerial disaster on his own planet, Terra, and that he had managed to save a two-month old baby. He and his charge had parachuted to an uninhabited island in the Tropics. A list of the plant and animal life on and around the island was attached. Problem—in a thousand words or less—how to feed the baby.

The endless questions and tests, which seemed to have no clear, discernible reason behind them, had finally begun to get him down. Only the fact that they all emanated from the legendary Survey & Contact Division had made him persevere, giving them the fullest and best attention of which he was capable. Somewhere, he forced himself to believe, a picture must be building up of his personality, brains, and all other attributes, and these bizarre exams and essays were just more steps on the road. He simply had to assume this.

Thus, when he had stared at the dust of the vanishing message on his desk, he got two new ideas. One, he was suddenly and absolutely sure that the summons was genuine, and two, that it would never be either confirmed or repeated. The disappearing paper was one

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little touch of mystery, maybe to simply pique his curiosity, perhaps yet another test of some kind. At any rate, it had to be pursued at once.

Powers had moved quickly in the next hour, very quickly indeed. He had called for directions through the Command Center, asking for the planetary location of Survey & Contact Headquarters. The stupidest clerk he had ever encountered had taken twenty minutes to find and report the location, which then turned out to be on the far side of the same continent which housed Command Division. Raging with impatience, Powers had ordered a special, one-man jet sled, and this also had been unaccountably delayed.

Using the highest speed possible, he had been exactly three minutes late when he braked down on a deserted landing strip near a quiet, blue arm of the ocean. Behind the strip rose a bulging, blobby gray building which seemed to have no basic design at all, and which showed no visible windows or doors. However, as Powers got out of the sled and narrowed his eyes against the sunlight, a figure appeared around a corner of the building, and moved slowly out to meet him.

As a commander in the Combine Navy, Powers had seen some strange members of the military services, but this specimen was outstanding. As he came to a leisurely halt in front of Powers, he brought a hand up in a sloppy salute.

He was a tall, powerfully-built, blond man in the green uniform of a sergeant, Special Landing Forces, and appeared to be a Terran. His insignia was tarnished, his boots dirty, and he needed a shave, the yellow stubble showing through a tanned skin. His whole posture was casual and insulting. He said nothing, just stood and blinked sleepily.

Keeping his temper barely under control, Powers returned the salute.

"At ease, Sergeant . . . if you aren't already. Is this place Survey & Contact, or an abandoned supply dump?"

"This is it," said the tall one lazily. "You got orders here?"

"Call me 'Sir,' " blared Powers. "I am Commander William Powers, and the orders were . . . well, they were verbal. Now brace up and take me inside before I get those stripes yanked off and charge you with being insolent as well as dirty and unshaven on duty."

The sergeant gulped and straightened up a little. "Sorry, Sir, I haven't had any field duty for a long time. Guess you get out of practice, huh, Sir? You got any luggage I can carry, Sir?"

Powers stared coldly at the man, but could read nothing in his eyes except stupidity and fright. How could Survey & Contact have an eight ball like this around to wel-

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come visitors, he wondered? He merely waved toward the building and they set off across the dusty landing strip, the sergeant in front.

The N.C.O. marched straight to an apparently blank wall and leaned on it. Silently, a door appeared, a black rectangular opening in the gray smoothness. The sergeant stood to one side and indicated that Powers precede him. It was not until Powers was in the corridor beyond that he realized the door behind him was closing. As he spun around, he heard a malicious cackle from outside.

"You're a hell of an officer. Three minutes late, yet!"

Then the door shut, as silently as it had opened. There was no knob or button on the inside.

Fuming, but also deciding to waste no more time, Powers had walked forward along a dimly-lit corridor, blank, gray walls revealing no opening. After about a mile of meaningless curves, all appearing the same, and passing nothing but a thousand atomo bulbs in the metal ceiling, he had suddenly emerged into the office in which he now sat. And had been sitting. And sitting . . .

The sour-faced prune behind the desk had spoken exactly twice, the first time when he came raging through the door.

"Commander Powers?" she had whined in Universal. "You are late. Please sit down and do not disturb me. I have work to do." The second time had been when he had commented on the heat.

Inwardly, he continued to seethe. The whole day so far had been one foul-up after another. Nothing had gone right from the moment he had received the message in his office. And now, after months of filling out gibberish forms and tests devised by lunatics calling themselves psychologists, he had finally cracked the portals of the fabulous Survey & Contact Branch. Hah! A madhouse staffed by rejects and morons! The minute someone in authority appeared he would politely ask the way out, leave and withdraw his application for Survey Service.

As he brooded over the wasted time and energy he had expended, a dull ache in his midsection reminded him that he needed lunch. He decided to check the time again and examined his wristchron. It still said 2:00 p.m. Annoyed, he held it to his ear. The thin hum of the atom battery was silent. Stopped! Sweet suffering epaullets! He had put in a new battery only two months before and they were good for three years! One more stinking item to add to a wasted day.

Across the now stifling room, the elderly woman continued to slowly scrawl on her pad. Powers decided that she had one of the most unpleasant faces he had ever seen. As he studied it for the fiftieth time, he suddenly thought it looked not only

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revolting but strangely familiar. Where in the cosmos could he have seen her before? Whatever the memory was, it evaded him, and he stared at the featureless brown wall again, determined not to speak. By God, if they wanted to annoy him, he would not be annoyed. An officer of the Senior Service had more control than that. He began to formulate abstract math problems in his head, his eyes fixed and unseeing.

At some indeterminate time later, Powers suddenly tensed, every sense alert. He was a graduate of the Lyran Nerve Training School, and his body had unmistakably sounded a subtle warning. It took a split second to identify what his system was being alerted against, and this was too long for him to take action or hold his breath. Sleep gas! Subtly it had filtered into the room and he was already going under. His last memory before he lost consciousness was one of surprise, because his eyes registered the flabby hag across the room writing steadily away, obviously unaffected. Then he passed out.

When he woke, it was with full consciousness of what had occurred, and he came to his feet with a rush, only to relax. He was in the same office as before, overheated, bare walls and desk, nothing changed. He was still hungry, sweating and irritated, but now had a headache as well. Then his eyes steadied on the figure behind the desk and he grew alert again.

A short, fat man with a long, droopy nose, again presumably Terran like himself, was smiling at him. The man was bald, looked about sixty years old and wore a featureless coverall of gray. Two scribers were clipped to his pocket, but nothing else gave a clue to his position in life. Powers studied the face in front of him and felt repelled. In lean, hard condition himself, the sight of the bloated body disgusted him and so did the oleaginous smile which was fixed on the sweating, jowled face.

The man spoke, using Slavang, the language of Terra, fluently, but with a guttural and unpleasant accent. Powers noticed that the smile never reached the cold, black eyes and readied himself again, sitting down as he did so and trying to appear at ease.

"I have a few questions, Commander," the man said. "Please answer them promptly and don't waste my time being indignant. You asked to be here, you know, we didn't send for you. You applied for Survey & Contact voluntarily." There was nothing pleasant about the thick, grating voice or the words, but the meaningless smile never left the fat countenance.

Powers gasped audibly because the other's statement had taken the wind out of his sails. His protest and request to withdraw his application died stillborn. After all, he

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had volunteered. Steadying himself, he nodded, incapable of calm speech.

With no more preamble, the fat man began a stream of brutally personal questions, noting the answers on a pad in front of him.

Did Powers like women? Sexually? What other ways? Was he sexually attracted to men? Had he ever been? Which women had he been attracted to? Where? Under what circumstances? How? What forms of love-making did he prefer? Had he experimented with women of other races than his own Caucasoid strain? With men? With creatures of other races? From other worlds? Did he go to joy houses? Alone?

Bill Powers was a healthy, and perfectly normal male, a bachelor, but no celibate. The stream of questions began to really disgust him, as they passed from personal to prurient, from clinical to obscene, while all the time the fat smile and the jet eyes never wavered. Biting his lip, Powers managed to contain himself, although barely, and continued his increasingly terse answers. Just when he felt that his patience was about to snap completely the questions stopped. The fat man folded his notebook pad and tucked it into a side pocket. Then he rubbed his fleshy hands together and placed them on the desk, before addressing Powers.

"Do you still wish to continue your application for Survey & Contact, Commander? If so, I must tell you that you are in mortal danger."

Hungry, hot, furious and baffled, Powers stared back at the cold eyes. Despite his intense irritation, he was conscious suddenly that he was being told the exact truth. The greasy smile had disappeared from his interrogator's face and the short figure had assumed both a menace and a dignity it had not previously possessed. The annoying accent was still present, but the voice was unmistakably sincere.

Powers thought hard for a moment. "Can I ask what you mean?" he said.

"You may ask, indeed," said the fat man. "My answer may not satisfy you. The next step in interrogation is a test, but a physical test—a survival test. I can give you no details whatsoever about it, but I can say this. Failure is lethal. Every member, real *member,* or Field Agent, of Survey & Contact, excluding hired help, has passed it. If you choose, you may return, as of this minute to your normal duties, and your regular service. There will be no mark on your record. You may become a Fleet Admiral and a very good one. But your application file for this branch will be closed and never reopened." He paused and then continued.

"There is one final point. The records of those who have failed this next test are also closed. Failure in this test, you see, means

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death. The percentage of failures is 37.9. I can allow you, by Survey & Contact regulations, *our* private regulations, exactly three minutes for a decision."

The words rang hollowly in the small room. 37.9! Failure is death! Powers thought desperately. This was insane. Get out of here quickly and forget the whole business. No one but a madman would consider such a lethal proposal. He looked up and heard the fat man speaking.

"All failures die. They are marked as dying in the line of duty. A full pension is paid to any person or persons designated."

Powers stared at the floor again, his strong hands clenching and opening convulsively. This was the end of the line. To hell with courage. Get out now, Powers!

He looked up and met the fat man's stare evenly, conscious even as he did so that breakfast might have been his last meal.

"I'll do it," he said flatly. "Do I sign anything, any release?"

He thought he detected a flicker of something, possibly respect in the jet eyes, but he couldn't be sure.

"Not necessary," was the answer. "The service regulations cover it. The test starts—now!"

Powers felt the Sleep gas hit again, but as he went under he knew surprise, for he could hear the fat man still talking, this time with no accent at all.

"Good luck, Son, and remember —never give up . . . never!"

Then all faded out again and was gone.

As he came awake, he was conscious of two things, the light and coolness. As he opened his eyes, a third, an up-and-down motion, was added to the other sensations. Finally, the fact that he was dripping wet was brought home to him with a vengeance as his head was suddenly buried in water, which made him choke. Fighting clear of it into the air, he spat out the liquid, finding that it was salt and bitter-tasting as well, and sat up, staring about him.

He was sitting on a tiny raft, a crude thing, low and awash in the water. Made of a few logs, loosely lashed together with what looked like vegetable fibers, the raft rode soggily on a dirty-looking sea. The ropes holding it together looked frayed and creaked audibly as the waves lifted the raft.

The water was dark and scummy-looking and the waves were mild. Overhead, a cloudy, brown sky hid the sun, but enough dim light came through so that Powers could see fairly well in every direction.

Looking down, he saw that he was almost naked, wearing only issue cloth shorts and a belt. He was barefoot. From the belt hung a short, heavy dagger, and he slipped the two-edged blade out of its metal sheath with satisfaction, testing its sharpness on his thumb.

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Then he stood up, balancing carefully on the two center logs of the four-log raft, and slowly turning his head. He could see nothing in any direction but one, save water. About a mile away, a rocky island rose out of the ocean, its sides sheer and menacing. No other object broke the limited horizon. A black structure which looked artificial and not natural crowned the island's height.

Sitting down, Powers drew his knife and cut off a tiny piece of wood from one of the logs. The wood was soft, waterlogged almost, but would still float. Throwing the chip over the side, he resheathed the knife and watched the movement of the piece of wood with one eye, while estimating the distance to the island with the other.

At the same time his mind was racing furiously. He assumed automatically that he had been knocked out by the Sleep gas, put in deep freeze and dumped on an alien planet. Unless, of course, he was in some monstrous environmental testing lab maintained by Survey & Contact for the purpose. This latter was possible though unlikely, from the sheer amount of space involved.

He checked the wood chip until it was out of sight and tried to estimate his speed. He was drifting at about one knot on a current right for the island, which was almost certainly no accident. Looking up, he could see it clearly in the gray light, even from a sitting position, and decided the raft would bring him to shore in about two hours, if nothing changed.

A faint drizzle, imperceptible almost as a mist, began to fall, but, although his exposed skin felt chilly, he was not acutely uncomfortable. The ocean, or whatever it was, seemed about 72° Farenheit and the air perhaps 10° cooler. He could survive a long time under such conditions. He was conscious of mild thirst but it was only mild, and the fact that he had missed lunch could be dismissed also. He might have been in deep freeze a month or ten seconds but he felt perfectly fit.

Keeping an eye on the island, already perceptibly closer, he began a careful examination of the raft. All the survival courses he had ever taken had stressed utilization of whatever unlikely materials were available. He could hear the instructor now at Grand Base O.C.S. during the castaway's course.

"Beings, remember! Examine and catalog what is available at once! If an emergency strikes, there will be no time!"

So far, nylon shorts and belt, metal buckle, seven-inch, two-edged knife, its metal sheath clipped to the belt, plus a sagging raft.

Just how sagging, he soon discovered. It was breaking up. The lashings as he had thought, were

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tattered bits of some plant fiber rope, and very few were still holding. Even as he watched, a section snapped, worn out by time and hard usage, and a log drifted away. The raft was only minutes away from dissolution with three logs left.

He thought quickly. Where in the universe could he be? Was that grimy-looking ocean dangerous? Although it tasted unpleasant, the flavor was more that of a dirty tide pool than something poisonous. But if harmless, what lived in it? It looked capable of concealing anything, and for the first time a thrill of fear ran through him. He could *die* on this test: almost half the applicants had, according to the fat man

Another fiber parted and the two logs supporting Powers' weight began to come apart at one end of the raft. At the same time paralysis seized him, numbing his muscles and sapping his nerve to the breaking point in a split second.

Out of the gentle curve of a wave, black and shining, a high, pointed fin had appeared mysteriously, no more than a few yards from the left side of the disintegrating raft. It stood at least a yard out of the water, the droplets gleaming from its smooth surface and then subsided as silently as it had come, leaving a man gaping at the dark water, frozen with a fear so stark and awful that his heart had almost stopped beating.

As a boy, Powers had been taken on a vacation to the South Pacific by his parents, to Rarotonga, and while swimming one day he had seen a native of the island seized and devoured by a huge Tiger shark, the clear water revealing every nasty detail. He never had got over it, and while not afraid of water, had never gone swimming alone since, nor entered any but clear, cold water, and fenced at that, if in an ocean. Now all the horrors rushed back and the screams of the long-dead native beat again upon his eardrums. He must be on Terra, some lost backwater of his own planet, and in front of him cruised a monster capable of shredding him apart in one bite.

But it was only for a second that he was bereft of control. A lifetime's arduous training and discipline overrode the panic, and he began to function as a reasoning being once more. He felt self-contempt wash out much of the fear.

A quick glance showed that the raft was almost gone. The two former center logs were tightly secured only at one end, by a loose strand in the middle where he crouched, and not at all at the other end behind him. He drew his knife, holding it blade up and looked at the island.

It now lay between one half and one quarter mile away. And for the first time he could see the black object which sprawled upon its peak. And this confirmed his decision. He was on Earth, on Terra itself. For before him, plainly visible, towered

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an ancient house, huge, colored in grays and blacks, with peaked roofs and chimneys and what looked like a myriad, black, gaping windows, staring out over the misty ocean.

Even as Powers fixed the identity of the house in his mind, the logs beneath him began to move apart. There was no delaying the decision, and while a tiny part of his mind still cowered in fear, shrieking "you'll be killed," it was overridden by his will.

He dived cleanly into the black water, and struck out for the island, using a side stroke which allowed him to keep his knife in his right hand.

As he rose on the first gentle wave, his stroke faltered. Two waves away, directly ahead and between him and the island, rose the towering dorsal fin. Now it had risen clear out of the water, and a six-foot length of shining black skin showed the back of whatever carried it.

But Powers had been driven too far by will, and in any case, could not now turn back if he wished. He had no place to go and knew it, except forward. He continued to stroke smoothly, straight for the island and the fin, too, although that had silently vanished again. His body seemed one giant nerve ending, keyed up to the surge of water against his skin which would give a useless warning of the monster's rush. But his knife was ready as ever, and he was prepared at least to leave a gash on its hide. A wave broke gently over his head, filling his open mouth with the taste of the water, salty and unpleasant, but his steady stroke never varied. On and on he went, numbing his imagination, swimming steadily and slowly for what seemed eternity.

And suddenly, he was there. His feet scraped bottom, and, hardly able to believe it, he staggered ashore on to a pebbled beach under the towering face of rock, and fell on the hard stones, his knees giving way from the strain and his heart pounding with relief.

It was at least five minutes, he estimated, before he could sit up. The prospect before him was not inviting, but at least he was on dry land and unharmed.

He was on a tiny beach, about ten yards long by eight deep, surrounded on all sides by walls of bleak, granitelike stone. No seaweed or shells lay on the margin to mark a tideline, and further back, no plants of any sort grew. He got up and began to examine his landing place carefully, noting absently that the light seemed to be decreasing. It must be evening, but the low cloud bank hid any trace of stars or sun, and the light was not that of a normal evening, anyway. His belief that he had been transported to Terra wavered for a moment, while he searched the desolate shingle for a clue as to where he might be.

The house! All at once the great

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house on the headland came back into his mind. He must be right below it. Even if it were empty, there would at least be shelter, and possibly food and water. There ought to be water at any rate.

Gloomily he studied the bleak walls of his temporary prison. The damp rock did not even have lichen growing on it. There was no other sign of life on the shore. He looked out to sea, but the visibility was far lower than when he had arrived. It was not night, but a gloomy dusk which now covered the waters.

Once again he circumnavigated the grim little beach, this time looking for footholds on the cliff. Above the center of the shingle, at its broadest point, the black face of the frowning rock actually leaned out, casting a deeper shadow, but at no place, even on the sides, was there a trace of footing. He found a small pool of water at one place, apparent seepage from the dank stones above, but it was evil-smelling and undrinkable.

This left the beach. Carefully, he waded out to the right-hand edge, holding on to the cliff as he did so. Where the cliff ended, his probing foot went down and he drew back hastily. He still could not see around the cliff. Looking out to sea again, he suddenly saw the great, black fin. It lay, almost motionless in the gentle swell, about fifteen yards off shore, a silent sentinel.

Shuddering involuntarily, he stepped quickly back on the beach and sat down. A gentle breeze had come up and the misty rain still fell, but the wind was barely audible and the regular plash of the tiny waves on the shingle was the only sound he could hear.

Sound! Perhaps the strange house was not empty! Springing up as the thought came to him, Powers yelled, funneling his hands around his mouth. Three times he bellowed, "Help," and then stood waiting, his ears straining. After a minute's silence, he tried again, and again stood listening.

This time he felt sure he heard something, but the answer was neither what he was expecting, nor was it reassuring.

From far above him there seemed to quaver for an instant a brief, high sound, somewhere between a wail and a shriek. It only lasted a moment, rising to an almost inaudible tremolo, and then abruptly ceased, so that Powers was left wondering if he had really heard anything at all. In the end, he decided that he had, but also that he could derive little comfort from the sound. Whatever made it did not have human vocal chords, and there had been an element of want and *hunger* in the keening cry which had impressed itself most thoroughly in the stiff hairs on the back of his skull. Something strange, eerie and half-remembered had come into his mind, leaving him momentarily shaken and nerveless.

He stood for a moment, arms

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rigidly folded, cursing the Survey & Contact Division under his breath and adding a final epithet for himself and his own stupidity in volunteering. Then, once again, he rallied and began to review the known facts he had to work with.

He was marooned on a rocky island, and there was an odd old-fashioned house. The house *looked* Terran, but the sea around the island tasted weird. Still, there was a monster shark offshore. But was it a shark? Other planets produced remarkably similar adaptations. Powers was neither a biologist nor an ecologist but he had done a lot of reading and he had seen similar life forms listed from several other worlds beside Earth. And now, there was that chilling sound his shouting had evoked from the clifftop. Some deep-buried memory, perhaps ancestral in nature, told him plainly that the sound he had heard was never produced by anything that walked on Earth. And yet there was that haunting sense of familiarity. Where was he?

Abruptly dismissing further speculation as profitless, he walked over to the left-hand end of the beach and began to wade out, as he had done earlier on the other side. The sheer cliff of the island came down just as sharply here, but to his delight he could wade around the corner of the cliff in no more than a foot or two of murky water.

Peering cautiously around the elbow of rock, he found he could see about a dozen yards clearly. There was no corresponding beach on the other side, but at first glance there appeared to be a slight inward angle to the cliff face, offering possible hand-holds for climbing.

Ever so carefully, keeping his left hand on the rock, he waded out, shuffling his naked feet, so as not to step into a pothole, or a sudden dropoff into deep water. He glanced once out to sea, but this time there was no sign of the fin.

About twenty feet along from the corner of the bay, he found what he was looking for. A narrow crack angled up the cliff on a steep, but not impossible, slant and, moreover, the cliff drew back a little, so that peering up, he could see the dark line which marked its top, even now through the brown and baffling dusk.

He decided to take one more precaution and waded inch by inch out into the water directly in front of the crack. As he expected, it deepened within two yards. Satisfied, he waded back to the base of the crack. If he became stuck higher up on his climb, he could at least leap out into the sea and try to make the little bay again by swimming.

Then he stood breathing deeply for a moment and said a silent prayer. At length, he began to climb. He did not like climbing heights and never had. In fact he dreaded it, but he was in good condition and his nerves were under

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rigid control. Keeping his face to the wall and looking up, not down. he made slow but steady progress. He had learned the basic elements of climbing long before in various survival schools, and he was surprised how easily they returned when needed from the depths of his memory. At one point a considerable distance above the sea, the crack widened suddenly into a narrow chimney, and he braced himself on both sides automatically, going up like an inchworm.

He felt the strain of unused muscles only slightly, but it was a relief to discover a small ledge fifty feet up the chimney on which he could sit and take a breather. The ledge had room only for his buttocks and his legs hung over the drop, but he could rest his back and relax, at least momentarily.

Looking out over the strange sea, he felt a chill, not of his skin, but from deep inside. What was this uncanny place? The light had faded even more, and although the fine rain had now stopped, the visibility was still dropping. And yet it was not a true night, but rather a dark, gloomy evening, which nevertheless maintained some odd, diffused source of light, never entirely absent. The wind had risen until it was audible as a faint moan, which added to the increasing unease in Powers' mind. He was conscious of a feeling of forlornness, of being hopelessly lost and adrift, which he had never felt before, and against which he had to continually brace himself if he were to keep going.

He gathered his feet under him on the ledge and got set to resume his progress up the cleft. Looking up, he saw with some surprise that the cliff edge was not very far away. He looked down briefly and estimated that he must have climbed at least two hundred feet, and now had another eighty or so to go. A brief wave of nausea made him turn quickly away to his task and he started to climb again.

Now he looked neither up nor down. Despite his rest on the ledge, he was becoming tired and he didn't dare use up any reserves of nervous energy getting frightened by heights. He just climbed, feeling for handholds and levering himself up in a steady, undeviating motion. The wind ruffled his hair, bringing no coolness, but rather a nasty feeling of delicate fingers probing for him, and its soughing on the damp rocks seemed to have a malignant note.

The clifftop came as a shock. His outflung arm, searching vainly for a new grip, encountered nothingness and a brief spasm of panic struck him before he looked up and saw the line of the top only a foot above his head, dark against the lighter sky. Drawing on a last store of energy, he gave a mighty heave and snapped his body over the top in one motion, to lie gasping on the moist ground. He lay face down, panting, the sweat pouring from his

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body, dead to everything but the need to rest.

When his starved lungs had finally fulfilled their need for air and his overstrained muscles stopped their spasmodic twitching, he sat up and stared about him, now cold again from congealed perspiration.

He was lying on the cliff's edge, at the bottom of a gentle slope. A yard from his position, a verge of brownish, tussocky grass led into a tangled mass of shrubbery and bushlike vegetation, with here and there a low tree, all tossing in the rising wind, their colors a variety of duns and brownish shades.

Rising out of the scrub and wood, about a half mile away, was the house he had seen from the sea, an enormous structure of peaked and crenellated roofs, broken chimneys and countless windows, black pits of emptiness in the gray walls.

As he stared at it, he saw that flecks of reddish light now played here and there over both the building and the surrounding foliage, and looking up, saw a vast dim, red moon had appeared, partly veiled by flying murk and cloud. It gave little light, and only added a mottled effect to the landscape, which was unpleasant enough anyway. The view now appeared both spectral and unclean, in some manner which disturbed the inner part of his being. The moon was far larger than that of Terra, but blank and featureless where the surface showed.

Looking at the house once again,

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Powers felt a tug of memory. Somewhere, he had a feeling, he had seen it before, and in some connection he did not like to recall. The feeling was momentary and he suppressed it quickly. Whatever the place looked like, he had to have shelter, for as the sweat cooled on his skin, he was aware of an icy chill which penetrated to his bones, and at the same time, thirst, not a severe problem until now, made itself felt as a sharp pang.

He stood up and unsheathing his knife stepped on to the edge of the shaggy grass. His bare feet, which were now sore from many small cuts, registered that it felt greasy and unpleasant, but it seemed to contain no thorns or brambles. In only a few steps he had crossed it and entered the shadow of the shrubbery. For as he entered it, he had realized that this was the correct word. He was in the ruins of some mighty garden or estate, surrounding the huge and apparently empty house like a barrier to keep out intruders. A few more cautious steps confirmed this view. He could not identify the low, wind tossed bushes around him or the larger trees that jutted up from their midst, but the whole appearance of the place was unmistakable.

As he stared about him in the strange half-light, he began to pick out overgrown paths, heavy with rank grass here and there through the bushes. In one place through the trees a faint gleam flickered momentarily as lighter than the rest, and seemed to speak of stone. As the identification registered on his forebrain, so, too, did his now acute thirst. Gardens should contain fountains, which meant stonework.

Stumbling slightly over the longer grass stems, he headed in the direction of the faint gleam. He found a dim, overgrown path which led that way, although winding here and there through the dark vegetation. Soon he emerged in an open space, and there, sure enough, was water.

It was a dark, round pool, perhaps twenty feet across, oily and repellent in aspect, backed by the broken wall of whitish stone, which he had seen in the distance. Patches of some bloated weed lay here and there on the still surface. The slimy, light brown roots of some water plant sprawled on the edge and spilled up and over into the rank grass which surrounded the verge.

Still, it was water and presumably fresh, and he now badly needed water. Crouching, one wary eye on the house, which now lay much closer and to his right front, he left the bushes and moved toward the nearest part of the silent pool.

As he did so, a strange and terrible thing happened. The fat, ropy tendrils of ochre weed which he had seen lying on the brink of the stonework lifted suddenly and began to wave and oscillate in the air, like monstrous feelers trying to grasp some unimaginable prey.

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He was no more than a yard or two from the water when it happened, but drew back convulsively to the edge of the bushes, and numb, stared at the thick dancing tentacles which whipped and vibrated all around the edge of the pool to a height of six feet. He had never seen a more disgusting sight, and he felt almost physically sick. Even as he watched, the movements began to slowly die down, until in a few moments the pool was once more still under the evil rusty moonlight, as calm as when he had first appeared.

He stood a moment more in concentrated thought. Whether animal or plant, the evil-looking guardian of the pool had clearly been somehow alerted by his approach. To try and get a drink from the water now would be madness, particularly since he had only a knife.

What particularly annoyed him, even more than his painful thirst, was his own fright. Since waking from the Sleep gas, he had been conscious of recurrent waves of fear passing through his system. Although he had mastered them and gone on, over one menace and obstacle to yet another, they were still surging against his inner being. As he raised his eyes to the great house, frowning above him, the fear returned again, so strongly that his body shook as if with an ague.

His mind fought the fear back, and he held his fist out stiffly until its trembling subsided and the dagger point ceased to waver. Helping him muster strength was a renewed feeling of rage, rage at Survey & Contact for dumping a man in this ghastly place and using the forces of some unknown area as a trap for an almost defenseless man.

Once again he started for the house. Skirting the neighborhood of the uncanny pool, he kept in the shadow of the trees and moved around the water in a wide circle. Although he watched carefully, he could not see any movement from the strange inhabitant which lurked there.

On the far side of the open space, he found, as he had expected, a continuation of the path which had brought him thus far. The tussocky grass was now knee-high, but the opening was unmistakable, and pointed straight up the slope toward the house.

As he entered the gap in the trees, the wind rose from a moan to a shriek, and glancing up, he saw the moon clearly, with only a few racing scuds of cloud to shield it. Then he knew that it was no moon he had ever seen before. It was not only a far larger orb, but the sickly red of its light was an actual color he had never before glimpsed.

Looking down again, he moved steadily on down the lane of windswept trees. He was not on Terra, but on something alien, some lost planet. But then, the house! How had that come here? Even as he

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pondered it, it appeared before him.

Clearly delineated in the moonlight, now grown brighter, it stood, less than a hundred yards away, across another belt of brown grass. The trees thinned back on both sides and so far as he could see, approached the place nowhere closer than the distance which separated him from the walls.

He had not realized the sheer bulk of the huge, stone building or its countless convolutions until now. It had four rows of windows in the main body, which was directly in front of him, but wings led off on both sides and innumerable towers, separate roofs and chimneys broke the outline. Here and there, small balconies and walks with black doorways behind them broke the outline of the walls. The place could have housed an army, he thought and realized that if it had ever done so it had been long ago. For the house walls were crumbling, piles of rock and rubble marking where weaker parts had long ago crashed to ruin. Holes were visible in the slanted main roof, and many of the chimneys were gaunt fingers of stone with two or three sides missing. Windows here and there were irregular in outline, as if etched out of their true shape by time's acid. And over all brooded a feeling of age, desolation and decay.

And more, of menace. As Powers swept the vast building with his gaze, he was suddenly and sharply aware of that. The monstrous pile might be crumbling and falling to the ground, but there was life somewhere about, inimical life, horrible in purpose. His brain, sent this message by some subtle chemistry of the body, filed and accepted the fact, and he steeled himself for an encounter, crouching to earth under a low shrub as he did so.

And suddenly he saw something. To his left, where a wing of the house extended beyond his vision, in one place a walk had been built into an angle of the building, at the highest level of windows and doors, just before the peaked roof actually started to rise. A crumbling stone balustrade marked the line of the walk along a fifty-yard stretch of the wall. His eyes, alerted by a half-seen flicker of movement, switched left and centered on the walkway.

Along it, at speed, came a great dark shape, moving at a lumbering yet fluid pace. It was hard to see details, but before the body passed from sight into a dark doorway further down the balcony, Powers had received several impressions.

One was of size. The thing he had seen was at least the size of a Terran bear, and not unlike it in outline and movement. But the head, in the one glimpse he had caught, was rounded and without visible ears. It had seemed to move on all fours, but he had an ugly and innate feeling that it could move on two almost as easily.

The total impression given him was one of mind-chilling stealth and

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ferocity, schooled into his brain by previous encounters with alien forms of life on a dozen worlds. Nowhere had he seen anything like this, and yet he knew it was dangerous, hideously dangerous, on the instant.

All these sensations flooded into his mind in a split second. Even as they were recorded, his ears were assailed by a cry, coming from *behind* him in the dark and tangled wilds of the forlorn and abandoned garden. It was, he realized instantly, the same noise he had heard when calling for help at the foot of the cliff, a shrieking wail, rising above the wind and dying away in a high, piercing tremolo. But it was now far louder and nearer. As he crouched, numbed by a new terror, it sounded again, closer still.

With the simultaneous realization that it must be on his track, Powers darted from cover, his limbs galvanized by desperation. Better the house and its lurking occupant than meeting the author of that horrid sound in the open. In the house, he had a chance at least to take cover. He raced for the building, momentarily not knowing or caring what might be hidden there, and hurled himself through an open ground floor window head first in a spaceman's roll. He hit with a thud on a stone floor, the breath driven out of his body, but still clutching the knife in the ready position.

Sparked by adrenalin, he staggered to his feet and peered out of one corner of the window, hoping to gain a view of whatever was following him. As he tried to muffle his gasps for breath and quiet his twitching nerves, he raked the space in front of the windows with his eyes. But only the tossing bushes in which he had recently sheltered, swaying in the wind, met his gaze. Under the fitful light of the red moon, the lank grasses waved undisturbed. Of whatever made that uncanny wail, no trace presented itself.

He swung back into the room of a sudden, damning himself internally for a careless fool. As he peered from the window, anything might have stolen upon him from the inner doorway of the small chamber in which he found himself. It was solid stone, walls, floor, ceiling, with no trace of any furnishings, the floor only faintly dusty. A man-sized doorway opened on to dimness beyond, but no door was in evidence.

Moving silently, but with every nerve thrilling, Powers went to the opening and peered into the dark beyond. His eyes were now well-accustomed to the poor light, and he found that he could see clearly.

The small room gave upon a long, high corridor, unlit except for patches of lessened dimness marking other doors. In both directions it ran away into darkness, but one glimpse off to the right gave him a flash of hope. This was a gap in the corridor wall which looked like the base of a stair.

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Once more checking the corridor for sound or movement, and finding neither, he gripped the knife firmly and ventured out of the room, moving slowly along to the right, every muscle taut as a wire.

Underfoot, the stone felt slimy and cold, but it was smooth and well-worn, presenting no obstacle to silent movement.

He passed the doorways of several rooms, four of them lit by the moonlight outside, to his right, and two on the inner wall, dark as tombs. In each case he braced himself for a sudden assault from one of the openings as he passed, but nothing happened and he soon found himself at the foot of the stair which he had hoped for before starting.

It was narrow, also of stone and seemed perfectly sound. It wound in a tight spiral and pausing at the foot, he tried to see up. He listened, to the point of straining his eardrums.

No sound broke the silence but the faint noise of the wind, outside, now muffled by the house walls. But another sense, one long-used, screamed "Beware" in his mind, and he continued to stand frozen while his tired and overwrought brain sought to identify it.

It was—scent! Musky, abominable and mephitic, a strange odor hung about the stairway. It was not strong, as if whatever had made it had not been present recently, but it was not stale either.

Powers had no doubt what the origin was and felt the panic rising to the surface again. The black bulk he had seen on the upper stories of the house had been here, and could use the stair.

He began to mount, testing each worn and greasy step and finding it firm beneath his sore feet. He nerved himself as he passed the small landing of the second floor, but heard and saw nothing. He went on.

Nothing happened at the third floor either, but he had no trouble realizing that his passage might still have been marked by a silent listener. Narrow windows, set high in the wall of the stairwell, gave some light, but he could not see out of them and could only continue his progress. He was acutely sensitive to each minute scuff of his feet on the smooth steps, his own breathing, which he fought to keep even and the noise of the wind outside, as it hummed around the house.

He arrived at the fourth landing, and far down inside his being, felt better. Some heritage from tree-dwelling ancestors made heights seem safer, he mused to himself, even as he stood waiting and listening.

The stairs climbed no higher. One doorway opened off the landing, just as in the ground floor, a rectangle of blackness. He tried to catch the elusive and acrid odor he had detected earlier, but it was

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gone. Gripping his knife, he passed through the doorway and found himself in another corridor.

This one appeared even longer than the one on the ground floor of the house, and it was far better lit. Not only were there windows admitting the rays of the red moon, but breaks in the roof were numerous as well, and the passage had piles of rubble here and there on its floor. The noise of the wind seemed suddenly louder, almost a yell as it raced through the many openings and surged down the length of the whole building.

For no particular reason, Powers turned right rather than left and began a slow reconnaissance of the corridor, watching for any place that might provide at least a temporary shelter, in which he could hide until daybreak. If there is such a thing as day in this place, said his weary mind.

He passed a doorway on his right, no different from any other, when he halted suddenly and spun back. There had been an actual door, and his tired brain had failed to register it. It was hung on great metal hinges and stood solidly, a great, unadorned mass of a seeming black wood, opening on the room or inward side. There was no bolt or lock.

He checked the corridor again, saw and heard nothing and then moved quickly into the room. Unlike the other he had seen, it was not completely empty. Several large timbers, fragments of old beams, lay scattered on the floor, and a large wooden chest, minus its top, stood in one corner, under the window.

Powers summoned his last reserves of energy and by sheer strength managed to close the heavy door on its harshly grating hinges. The noise he made terrified him but there was no help for it. Dragging over the largest fragment of beam, he made a sturdy brace against it, and then sat down, facing the window and the moonlight. He noted idly, while listening, that a small hatch was set in one wall, the left, which might communicate with some forgotten pantry and that it seemed to have something dark like rotted velvet stuffed back in its recesses. A vague unease about the *texture* of what he had noted in passing made him look back again. And this time he saw movement where the material had been.

Into the room, slowly and with infinite caution there came a hand. It was five fingered and each huge finger was tipped with a polished claw. The hand and the colossal arm behind it were furred in black, closelying pelage, which he had mistaken for velvet. It moved slowly and stealthily in his direction, already as long as his leg and twice as big around. With it came a wave of the foul and sickening odor.

Frozen momentarily, he saw his error. The hatch he had seen was actually a connecting window to the next room and he had awakened

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what was lying there when he moved the beams and braced the door.

A great gust of fury awakened in his exhausted body. Just when he had found a shelter, some hideous thing sought to devour him! Within a bare second of his moment of discovery, he sprang across the room and with his knife, slashed at the groping black limb, aiming at the inner elbow, and hoping to sever a tendon.

The arm jerked back like lightning, and simultaneously, he was almost deafened by a scream of rage and pain which shook him physically with its sheer volume.

He leaped back, alert, his gaze fixed on the little window and saw, framed in its square, filling it from side to side, the visage which guided the arm

The face was twice the size of a man's and rather like that of a colossal cat. Black fur covered it to the blunt, naked muzzle, which was damp and wet. The eyes were huge, red and lambent, with vertical, black pupils, and he could just see tiny, upright ears on the sides of the great head. The wide, lipless mouth opened and again he was deafened by that awful cry, even as he saw the terrible teeth, a row of razor-sharp carnassials. The stench of the brute filled the room like a fog, but as he poised, ready for further battle, he saw with satisfaction that dark drops and pools on the floor showed his own power. He waited, tired but alert, for the monster's next move, his eyes fixed on that dreadful face.

As he waited for the next attack, the beast screamed again. But the cry was different, higher and wailing, even though it still left the man shaking from sheer vibration. And all the time, the strange eyes never left him, their stare of concentrated malignancy seeming to will him to remain, to freeze there and never move.

And even as that thought crossed his mind, a faint sound from outside came to his ears through the window, and he knew the bitter taste of his own folly. He had ignored all the warnings, the scream in the garden as he entered the house, the almost simultaneous shape on the balcony that he had watched, and now the familiar wailing howl from the wounded animal, followed by the scrape of claws outside. *The balcony ran outside this very room, and there were two hunters, not one!*

All this flashed through his mind as he was moving. The beast in the next room could never get through the connecting window. All he had to do was stay out of its reach. He dropped his knife and spinning to the old chest he had noted in the far corner, lidless and battered, he stooped and with a convulsive effort raised it from the ground. Half hurling and half pushing it, he aimed it straight at the outer window and his timing could not have been better, although it was largely luck.

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As the second hideous head rose to the window level, preparing to scramble in, a hundred pounds of ancient but solid wood struck it squarely with all the force a tired but powerful and desperate man could put behind it.

A massive crunch was followed by an awful, choked-off snarl and scrabbling sounds and then the window was clear again. From far below came the sound of something heavy hitting the ground with a squashy impact.

Powers had fallen to his knees, and, still on them, turned to face his original enemy. But the small connecting window was also empty. Must get up, he thought, and find that knife. But he could not rise. And the room was getting darker, much darker. His strong body was at last betraying him, when he needed it most, giving way to all the physical effort that had been demanded of it, giving way to the hours of fear and tension, the lack of food and water. The other one will come in the window, said his mind: fight! Once more he tried to rise and do battle and actually managed to totter erect, even as the room went completely black and he knew that he was falling forward. He never even felt the floor as he hit.

Which, under the circumstances, was not really too surprising.

"He's coming out now," said a voice. "The last shot should do it. Keep his arm immobilized as long as that tube is in it. Twenty more units of Adrenergon before his balance is built up again."

Powers was aware of being alive and comfortable even before opening his eyes. He felt tired. But pleasantly so, and cool and clean as well. Something soft covered his recumbent body and a pleasant odor, fresh and bracing, was in the air he breathed. Stretching ever so slightly, still only partly awake, he felt his right arm immobilized and the feeling brought all his memories back in a wave, causing him to try to sit up, his eyes open with shock.

"Easy, easy, Commander." A firm hand on his chest and another on his left shoulder kept him from moving. A tall, blond man of his own age was smiling down at him, his arms restraining any movement. Powers blinked stupidly at him and then stared past him at the others in the large room. All present, but one, wore white coveralls.

A short, elderly man with an aquiline, clean-shaven face and a stubble of cropped, gray hair stood grinning at the foot of Powers' bed. Next to him, also smiling pleasantly, was a handsome gray-haired woman. And lounging against the far wall was the tall figure of a Lyran, wearing service Blacks with no insignia, his great goggling eyes fixed oddly on Powers' face, his greenish tail curled neatly around one leg, making his race look even more than usual like monstrous parodies of Terrestrial chameleons.

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Powers lay back under his white sheet, idly noting the bustle of a group of human technicians, farther back still, who were moving some massive equipment from the room on silent wheels. He also noted the tube inserted in his arm and leading to a hospital intravenous feeding unit.

"O.K.," said the blond man who had been holding him down. "Stay quiet, don't move and you can talk. We're here to answer questions. But let me say one thing first. You graduated."

A sense of lassitude almost stopped Powers from answering, but he was too curious.

"Where was it? What planet was I on?"

The older man at the bed's foot answered. "No one will ever land there, or ever has, Commander. You are its first, last and only inhabitant and always will be."

"That's impossible," said Powers. "How did you get me there? How did you get me away? And what about those black demons and the . . ." He stopped, because all those in the room were smiling except the Lyran who could not, and he was emitting the leaking-kettle noise which passed for laughter with his race. A light began to gleam in Powers' eyes and his mind started to race furiously. He was in a hospital. Had he ever left it?

"He's getting it," said the woman. "Let's put him out of his misery quickly. Commander, you have spent six Galac hours, no more, battling the deadliest dangers, the most vicious adversaries in the galaxy, as well as surmounting the worst obstacles known to man. But none of us can ever really go where you have gone, see what you have seen or do what you have done.

"You see," she continued pleasantly, "You have fought monsters of your own creating, battled difficulties existing only in your own imagination, dredged from the worst horrors of your subconscious fears and dreads. You have never left this building, never moved a muscle in actuality, except to tense one occasionally." She paused.

"I'll take over," the older man said. "Ever see the clown who was just holding you, Commander?"

Powers glanced at the tall, blond man, then shook his head. This would take a whole lot of time to sort out.

"Think of him in a dirty uniform, unshaven and with Landing Force insignia."

Powers stared again, then smiled in recognition.

"Yes, I remember. He met my flier at the building. Why?"

"Annoyed you, didn't he?" was the question.

"Yes, he did. So did that hag in the office and that toadstool of a psychiatrist. Again why? What does it prove?"

This time he flushed when he saw them all grinning.

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"Yes," smiled the woman. "I'm the hag. Dr. Anna Fradkin at your service. We're rather good at disguise around here. I was made up as a grade-school teacher you once had and whom you loathed. Pretty good research, eh? The ex-sergeant, very ex, is Inspector Jared Morgan of the Terran Criminal Police. Sakh Mazzechaz of Lyra Seven is against the wall. And our toadstool psychiatrist with the disgusting interest in sex is at the foot of your bed. Galac Rear Admiral Dulip Singh, to be formal."

Powers could only gape at this point, but the smiling flag officer helped ease his bewilderment.

"Look, Powers, relax. You are now, and only now, a Galac Field Agent of Survey & Contact. You've passed the final tests. There's a lot more to learn but it's school work, although some of it can be rough.

"Survey & Contact has a very small corps. Human and nonhuman, and we're a minority, there are only about three thousand Field Agents. Not many for a galaxy, largely unexplored, eh?

"You've been tested for over a year. Your mail has been read, your messages, oral and written, monitored. You've been spied on, checked, watched and studied. Those forms and tests you filled out were like the one seventeenth or whatever of an iceberg that appears above water. We know you pretty well. Frankly, we planted the original idea of joining us in a thousand, subtle ways. We do it all the time, although most never get here at all. We are always looking for new people. The good ones are scarce.

"If we had found anything we didn't like, you'd never have joined. It would have been harmless, but you would have lost interest. We have some pretty good psych people, too. Survey & Contact still would be a mystery to you, and not an interesting one at that.

"All right, we had brought you to a certain point. We could go no farther. The final test was devised by . . . well, never mind, some day you'll learn, if you live that long.

"Anyway, this morning was it. Disappearing messages, late fliers, no lunch, endless waiting, a busted chron, dirty, unkempt sergeants, nasty prying about sex, alternate jolts of gas, we arranged all of it. Getting a picture? Then, bingo, a threat of death and you're out like a light again. You're strapped in, the electronics wizards connect their gadgets, and you're on your own. In the worst possible place you can think of. The bottom of your own subconscious dread, fighting the demon world of your own Id! You see, a world, even a universe, that you loathe and fear can be induced, forced to appear in your mind.

"Don't ask me how it's done. That's not my area. You may have a leaning that way yourself. If so, we'll find it. But to get back to the point, you were on a ghastly world filled with childhood fear symbols,

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half-remembered ghost stories, everything you *personally* were afraid of, most afraid of, I should say—like that house. A search of your early childhood on Terra disclosed that you had to pass one on your way to school, an empty, old, 'haunted' house that looked like that, and it must have scared Hell out of you so *you* brought it back. We could follow you on some of it by means of instruments, but you'll have to tell us the rest later. We need the data for our files.

"At any rate, we had you, irritated, tired, enraged, frustrated, and —*keyed up to the highest nervous pitch*, which is the only point to all the petty irritations, we had you on, or in as I said, this awful place. You had to fight or go under. Now get this. Those statistics I gave you back in the office were absolutely truthful. You could have been killed. A lot of good men and women have been. So have many other entities. Some minds simply cannot take what they call up out of their own depths. It's the last, ultimate test for a flaw. If you can keep coming, never stop, and never let up, against the worst *in your own subconscious,* you can't be stopped by anything. Killed, physically, of course, but not stopped." He paused. "Any questions?"

Powers felt numbed and overwhelmed by what he had heard, but he still had things to ask.

"What happens now, Sir, about my regular service, I mean?"

"You'll be transferred, probably to Supply & Requisitions. And be promoted steadily in grade. We have no rank, only assignments. Today you obey me. Tomorrow—the reverse. You may make admiral, but I doubt it. Too impetuous.

"And then you'll go to school. Our school. And go to work. But no one will ever know. What else?"

"Well, the gentle being from Lyra, has he something special to say to me?"

"Oh, him." Admiral Singh turned and winked at Mazzechaz, who politely snapped a nictitating membrane in a return gesture.

"Seems he wants you for a partner. He liked your total profile in our files. We all have them, partners, that is, to begin with, sometimes permanently. Don't know what he saw in you, myself. More?"

Powers sat up and stared at the faces around him. It all seemed unbelievable, but it must be true.

"Is this graduation, Sir?"

"All you'll ever get, Son. Now we'll clear out, let you get some rest. Oh, yes, one more thing." The admiral assumed a rigid posture, a deadpan expression.

"Do you still want to join?"

Powers was awfully tired, but he managed to rise to the occasion.

"Hell, yes, it beats work, I guess."

There was a long silence from all those around the bed and then the tall Lyran spoke for the first time, in a sibilant whisper.

"Welcome, Brother." ■

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Dragonrider

Conclusion. The dreaded Threads came—but even knowing when and where to meet them wasn't going to help much. There simply weren't enough Dragons for the job. . .

ANNE MCCAFFREY

Illustrated by John Schoenherr

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SYNOPSIS

F'LAR, bronze dragonrider, is attempting to ready the planet PERN's one Weyr, with its incomplete complement of dragons, to do the work of six as the fabled Red Star—erratic sister-world of Pern—approaches after a four-hundred-year lapse. During her fifty-year conjunction, the Red Star launches mindless elongated mycorrhizoid spores through space; they invade Pern, destroying anything green and causing lethal injuries to animal tissue. F'LAR teaches his new Weyrwoman, LESSA, the almost instantaneous method of flying between *places, mounted on her queen dragon, RAMOTH.*

Bored with the simple exercise of going from here to there, and partly by her amateurish failure to envision correct reference points, LESSA goes dragonback to her home Ruath Hold—thirteen years before. She discovers that her hovering in the sky on a dragon is one of the reasons why Ruath Hold was conquered, her family killed, herself alerted to hide and survive. F'LAR is outraged at her lack of discipline but comforts her when he realizes she is in deep shock; then tries the stunt himself on his bronze dragon, MNEMENTH.

Convinced and enlightened as to the "premonition" that had driven him to supplant R'GUL as Weyrleader, he tries to make use of this unsuspected dragon-talent in the looming battle with the Threads. LESSA and F'LAR search the Records of all six Weyrs for further hints of how to strengthen their methods and numbers, for dragonmen have fallen into disrepute and desuetude during the four-hundred year respite.

RAMOTH lays a mighty clutch of eggs, including a queen egg, which LESSA sees as a means of diverting young KYLARA from her pursuit of F'LAR.

The first Threads fall while the weather is still cold and turn to mere black dust. F'LAR takes a large detachment of flame-breathing dragons back two hours to dawn in Nerat and manages to be there when the first viable fall of Threads occurs. He suffers heavy losses and the next fall is due in three days. They have put up a great fight, but how long can they hold out?

In desperation, F'LAR and LESSA decide to send the new queen, PRIDITH, along with her weyrmate, KYLARA, and the young dragonets of RAMOTH's first clutch, back ten years between *times to the long neglected southern continent, if it turns out to be habitable. The venture, under the leadership of F'LAR's half brother, F'NOR, will breed up the young dragonets and, hopefully, several clutches from PRIDITH, to augment the Benden dragons.*

No sooner have F'LAR and LESSA agreed on this expedient, than F'NOR, tanned, distraught,

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haggard, appears to report that they cannot last much longer in the southern Weyr: that KYLARA is making trouble and all are suffering from fatiguing temporal sickness. Before he can be questioned, he staggers from the room.

PART II

F'lar stared after his half-brother, his brows contracting with the keen anxiety he felt.

"What can have happened?" Lessa demanded of the Weyrleader. "We haven't even told F'nor. We ourselves just finished considering the idea of exploring the southern continent: to see if we could send dragons back and give Pridith a chance to lay a few clutches. And he looked so tanned and healthy." Her hand flew to her own cheek. "And the Threadmark—I dressed it myself tonight—it's gone. Gone. So he's been gone a long while." She sank down to the bench.

"However, he has come back. So he did go." F'lar remarked slowly in a reflective tone of voice. "Yet we now know the venture is not entirely successful even before it begins. And knowing this we have sent him back ten Turns for whatever good it is doing." F'lar paused thoughtfully. "Consequently we have no alternative but to continue with the experiment."

"But what could be going wrong?"

"I think I know and there is no remedy." He sat down beside her, his eyes intent on hers. "Lessa, you were very upset when you got back from going *between* to Ruatha that first time. But I think now it was more than just the shock of seeing Fax's men invading your own Hold or in thinking your return might have been responsible for that disaster. I think it has to do with being in two times at once." He hesitated again, trying to understand this immense new concept even as he voiced it.

Lessa regarded him with such awe that he found himself laughing with embarrassment.

"It's unnerving under any conditions," he went on, "to think of returning and seeing a younger self."

"That must be what he meant about Kylara," Lessa gasped, "about her wanting to go back and watch herself . . . as a child. Oh, that wretched girl!" Lessa was filled with anger for Kylara's self-absorption. "Wretched selfish creature. She'll ruin everything."

"Not yet," F'lar reminded her. "Look, although F'nor warned us that the situation in his time is getting desperate, he didn't tell us how much he was able to accomplish. But you noticed that his scar had healed to invisibility, consequently some Turns must have elapsed. Even if Pridith lays only one good-sized clutch, even if just the forty of Ramoth's are mature enough to fight in three days' time, we have accomplished something. Therefore, Weyrwoman," and he noticed

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how she straightened up at the sound of her title, "we must disregard F'nor's return. When you fly to the southern continent tomorrow, make no allusion to it. Do you understand?"

Lessa nodded gravely and then gave a little sigh. "I don't know if I'm happy or disappointed to realize, even before we get there tomorrow, that the southern continent obviously will support a Weyr," she said with dismay. "It was kind of exciting to wonder."

"Either way," F'lar told her with a sardonic smile, "we have found only part of the answers to problems one and two."

"Well, you'd better answer number four right now!" Lessa suggested. "Decisively!"

Weaver, Miner, Harper, Smith,
Tanner, Farmer, Herdsman, Lord,
Gather wingsped, listen well
To the Weyrman's urgent word.

They both managed to guard against any reference to his premature return when they spoke to F'nor the next morning. F'lar asked brown Canth to send his rider to the queen's weyr as soon as he awoke and was pleased to see F'nor almost immediately. If the brown rider noticed the curiously intent stare Lessa gave his bandaged face, he gave no sign of it. As a matter of fact, the moment F'lar outlined the bold venture of scouting the southern continent with the possibility of starting a weyr ten Turns back in time, F'nor forgot all about his wounds.

"I'll go willingly only if you send T'bor along with Kylara. I'm not waiting till N'ton and his bronze are big enough to take her on. T'bor and she are as . . ." F'nor broke off with a grimace in Lessa's direction, ". . . well, they're as near a pair as can be. I don't object to being . . . importuned, but there are limits to what a man is willing to do out of loyalty to dragonkind."

F'lar barely managed to restrain the amusement he felt over F'nor's reluctance. Kylara tried her wiles on every rider and, because F'nor had not been amenable, she was determined to succeed with him.

"I hope two bronzes are enough. Pridith may have a mind of her own, come mating time."

"You can't turn a brown into a bronze!" F'nor exclaimed with such dismay F'lar could no longer restrain himself. "Oh, stop it!" And that touched off Lessa's laughter. "You're as bad a pair," he snapped, getting to his feet. "If we're going south, Weyrwoman, we'd better get started. Particularly if we're going to give this laughing maniac a chance to compose himself before the solemn Lords descend. I'll get provisions from Manora. Well, Lessa? *Are* you coming with me?"

Muffling her laughter, Lessa grabbed up her furred flying cloak and followed him. At least, the adventure was starting off well.

F'lar grabbed the pitcher of *klah*

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and his cup and adjourned to the Council Room, debating whether to tell the Lords and Craftmasters of this southern venture or not. The dragon's ability to fly *between* times as well as places was not yet well known. The Lords might not yet realize it had been used the previous day to forestall the Threads. If he could be sure that project was going to be successful, well, it would add an optimistic note to the meeting.

Let the charts, with the waves and times of the Thread attacks clearly visible, reassure the Lords.

The visitors were not long in assembling. Nor were they all successful in hiding their apprehension and the shock they had received now that Threads had again spun down from the Red Star to menace all life on Pern. This was going to be a difficult session, F'lar decided grimly. He had a fleeting wish, which he quickly suppressed, that he had gone with F'nor and Lessa to the southern continent. Instead, he bent with apparent industry to the charts before him.

Soon there were but two more to come. Meron of Nabol (whom he would have liked not to include for the man was a troublemaker) and Lytol of Ruatha. He had sent for Lytol last because he did not wish Lessa to encounter the man. She was still overly and, to his mind, foolishly, sensitive over resigning her claim to Ruatha Hold for Lady Gemma's posthumous son. Lytol as Warder of Ruatha, had a place in this conference. The man was also an ex-dragonman, and his return to the Weyr was painful enough without Lessa compounding it with her resentment. Lytol had turned to the Weaver's craft after his dragon's death and his compulsory exile from the Weyr. He was, with the exception of young Larad of Telgar, the Weyr's most valuable ally.

S'lel came in with Meron a step behind him. The Holder was furious at this summons; it showed in his walk, in his eyes, in his haughty bearing. But he was also as inquisitive as he was devious. He nodded only to Larad among the Lords and took the seat left vacant for him by Larad's side. Meron's manner made it obvious that that place was too close to F'lar by half a room.

The Weyrleader acknowledged S'lel's salute and indicated the bronze rider should be seated. F'lar had given thought to the seating arrangements in the Council Room, carefully interspersing brown and bronze dragonriders with Holders and Craftsmen. There was now barely room to move in the generously proportioned cavern, but there was also no room in which to draw daggers if tempers got hot.

A hush fell on the gathering and F'lar looked up to see that the stocky, glowering ex-dragonman from Ruatha had stopped at the threshold of the Council. He slowly brought his hand up in a respectful

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salute to the Weyrleader. As F'lar returned the salute, he noticed that the tic in Lytol's left cheek jumped almost continuously.

Lytol's eyes, dark with pain and inner unquiet, ranged the room. He nodded to the members of his former wing, to Larad and Zurg, head of his own Weaver's Craft. Stiff-legged he walked to the remaining seat, murmuring a greeting to T'sum on his left.

F'lar rose.

"I appreciate your coming, good Lords and Craftmasters. The Threads spin once again. The first attack has been met and seared from the sky. Lord Vincet," and the worried Holder of Nerat looked up in alarm, "we have dispatched a patrol to the rainforest to do a low-flight sweep to make certain there are no burrows."

Vincet swallowed nervously, his face paling at the thought of what Threads could do to his fertile, lush holdings.

"We shall need your best junglemen to help . . ."

"Help . . . but you said . . . the Threads were seared in the sky?"

"There is no point in taking the slightest chance," F'lar replied, implying the patrol was only a precaution instead of the necessity he knew it would be.

Vincet gulped, glancing anxiously around the room for sympathy—and found none. Everyone would soon be in his position.

"There is a patrol due at Keroon and at Igen," and F'lar looked first at Lord Corman, then Lord Banger who gravely nodded. "Let me say, by way of reassurance, that there will be no further attacks for three days and four hours." F'lar tapped the appropriate chart. "The Threads will begin approximately here on Telgar, drift westward through the southernmost portion of Crom, which is mountainous, and on, through Ruatha and the southern end of Nabol."

"How can you be so certain of that?"

F'lar recognized the contemptuous voice of Meron of Nabol.

"The Threads do not fall like a child's tumble-sticks, Lord Meron," F'lar replied. "They fall in a definitely predictable pattern; the attacks last exactly six hours. The intervals between attacks will gradually shorten over the next few Turns as the Red Star draws closer. Then, for about forty full Turns, as the Red Star swings past and around us, the attacks occur every fourteen hours, marching across our world in a time-table fashion."

"So *you* say," Meron sneered and there was a low mumble of support.

"So the Teaching Ballads say," Larad put in firmly.

Meron glared at Telgar's Lord and went on, "I recall another of your predictions about how the Threads were supposed to begin falling right after Solstice."

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"Which they did," F'lar interrupted him. "As black dust in the Northern Holds. For the reprieve we've had, we can thank our lucky stars that we have had an unusually hard and long Cold Turn."

"Dust?" demanded Nessel of Crom. "That dust was Threads?" The man was one of Fax's blood connections and under Meron's influence: an older man who had learned lessons from his conquering relative's bloody ways and had not the wit to improve on or alter the original. "My Hold is still blowing with them. They're dangerous?"

F'lar shook his head emphatically. "How long has the black dust been blowing in your Hold? Weeks? Done any harm yet?"

Nessel frowned.

"I'm interested in your charts, Weyrleader," Larad of Telgar said smoothly. "Will they give us an accurate idea of how often we may expect Threads to fall in our own Holds?"

"Yes. You may also anticipate that the dragonmen will arrive shortly before the invasion is due," F'lar went on. "However, additional measures of your own are necessary and it is for this that I called the Council."

"Wait a minute," Corman of Keroon growled. "I want a copy of those fancy charts of yours for my own. I want to know what those bands and wavy lines really mean. I want . . ."

"Naturally you'll have a timetable of your own. I mean to impose on Masterharper Robinton," and F'lar nodded respectfully towards that Craftmaster, "to oversee the copying and make sure everyone understands the timing involved."

Robinton, a tall, gaunt man with a lined, saturnine face, bowed deeply. A slight smile curved his wide lips at the now hopeful glances favored him by the Hold Lords. His craft, like that of the dragonmen, had been much mocked and this new respect amused him. He was a man with a keen eye for the ridiculous, and an active imagination. The circumstances in which doubting Pern found itself were too ironic not to appeal to his innate sense of justice. He now contented himself with a deep bow and a mild phrase.

"Truly all shall pay heed to the master." His voice was deep, his words enunciated with no provincial slurring.

F'lar, about to speak, looked sharply at Robinton as he caught the double barb of that single line. Larad, too, looked around at the Masterharper, clearing his throat hastily.

"We shall have our charts," Larad said, forestalling Meron who had opened his mouth to speak, "we shall have the Dragonmen when the Threads spin. What are these additional measures? And why are they necessary?"

All eyes were on F'lar again.

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"We have one Weyr where six once flew."

"But word is that Ramoth has hatched forty more," someone in the back of the room declared. "And why did you Search out still more of our young men?"

"Forty as yet unmatured dragons," F'lar said aloud, privately hoping that this southern venture would still work out. There was real fear in that man's voice. "They grow well and quickly. Just at present, while the Threads do not strike with great frequency as the Red Star begins its Pass, our Weyr is sufficient . . . if we have your cooperation on the ground. Tradition is that," and he nodded tactfully toward Robinton, the dispenser of Traditional usage, "you Holders are responsible for only your dwellings which, of course, are adequately protected by firepits and raw stone. However, it is spring and our heights have been allowed to grow wild with vegetation. Arable land is blossoming with crops. This presents a vast acreage vulnerable to the Threads which one Weyr, at this time, is not able to patrol without severely draining the vitality of our dragons and riders."

At this candid admission, a frightened and angry mutter spread rapidly throughout the room.

"Ramoth rises to mate again soon," F'lar continued, in a matter-of-fact way. "Of course in other times, the queens started producing heavy clutches many Turns before the critical solstice, and more queens. Unfortunately, Jora was ill and old, and Nemorth intractable. The matter . . ." He was interrupted.

"You dragonmen with your high and mighty airs will bring destruction on us all!"

"You've yourselves to blame," Robinton's voice stabbed across the ensuing shouts. "Admit it one and all! You've paid less honor to the Weyr than you would your watchwher's kennel—and that not much! But now the thieves are on the heights and you are screaming because the poor reptile is nigh to death from neglect. Beat him, will you, when you exiled him to his kennel because he tried to warn you, tried to get you to prepare against the invaders? It's on *your* conscience, not the Weyrleader's nor the dragonriders, who had honestly done their duty these hundreds of Turns in keeping dragonkind alive . . . against all your protests. How many of you," and his tone was scathing, "have been generous in thought and favor towards dragonkind? Even since I became Master of my craft, how often have my Harpers told me of being beaten for singing the old songs as is their duty? You earn only the right, good Lords and Craftsmen, to squirm inside your stony Holds and writhe as your crops die aborning." He rose.

" 'No Threads will fall. It's a Harper's winter tale' " he whined, in faultless imitation of Nessel.

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" 'These dragonmen leech us of heir and harvest' " and his voice took on the constricted, insinuating tenor that could only be Meron's. "And now the truth is as bitter as a brave man's fears and as difficult as mockweed to swallow. For all the honor you've done them, the dragonmen should leave you to be spun on the Threads' distaff."

"Bitra, Lemos and I," spoke up Raid, the wiry Lord of Benden, his blunt chin lifted belligerently, "have always done our duty to the Weyr."

Robinton swung round to him, his eyes flashing as he gave that speaker a long, slow look.

"Aye, and you have. Of all the Great Holds, you three have been loyal. But you others," and his voice rose indignantly, "as spokesmen for my Craft, I know, to the last full stop in the score, your opinion of dragonkind. I heard the first whisper of your attempt to ride out against the Weyr." He laughed harshly and pointed a long finger at Vincet. "Where would you be today, good Lord Vincet, if the Weyr had *not* sent you packing back, hoping your ladies would be returned you? All of you," and his accusing finger marked each of the Lords of that abortive effort, "actually rode against the Weyr because . . . 'there . . . were . . . no . . . more . . . Threads!' "

He planted his fists on either hip and glared at the assembly. F'lar wanted to cheer. It was easy to see why the man was Masterharper and he thanked circumstance that such a man was the Weyr's partisan.

"And now, at this critical moment, you actually have the incredible presumption to protest against any measure the Weyr suggests?" Robinton's supple voice oozed derision and amazement. "Attend what the Weyrleader says and spare him your petty carpings!" He snapped those words out as a father might enjoin an erring child. "You were," and he switched to the mildest of polite conversational tones as he addressed F'lar, "I believe asking our cooperation, good F'lar? In what capacities?"

F'lar hastily cleared his throat.

"I shall require that the Holds police their own fields and woods, during the attacks if possible, definitely once the Threads have passed. All burrows which might land must be found, marked and destroyed. The sooner they are located, the easier it is to be rid of them."

"There's no time to dig firepits through all the lands . . . we'll lose half our growing space . . ." Nessel exclaimed.

"There were other ways, used in olden times, which I believe our Mastersmith might know," and F'lar gestured politely toward Fandarel, the archetype of his profession if ever such existed.

The Smith Craftmaster was by several inches the tallest man in the Council Room, his massive shoulders and heavily muscled arms

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pressed against his nearest neighbors, although he had made an effort not to crowd against anyone. He rose, a giant tree-stump of a man, hooking thumbs like beast-horns in the thick belt that spanned his waistless midsection. His voice, by no means sweet after Turns of bellowing above roaring hearths and hammers, was, by comparison to Robinton's superb delivery, a diluted, unsupported light baritone.

"There were machines, that much is true," he allowed in deliberate, thoughtful tones. "My father told me of them as a curiosity of the Craft. There may be sketches in the Hall. There may not. Such things do not keep on skins for long," and he cast an oblique look under beetled brows at the Tanner Craftmaster.

"It is our own hides we must worry about preserving," F'lar remarked to forestall any inter-craft disputes.

Fandarel grumbled in his throat in such a way that F'lar was not certain whether the sound was the man's laughter or a guttural agreement.

"I shall consider the matter. So shall all my fellow craftsmen," Fandarel assured the Weyrleader. "To sear Threads from the ground without damaging the soil may not be so easy. There are, it is true, fluids which burn and sear. We use an acid to etch design on dagger and ornamental metals. We of the Craft call it agenothree. There is also the black heavy-water that lies on the surface of pools in Igen and Boll. It burns hot and long. And, if as you say, the Cold Turn made the Threads break into dust, perhaps ice from the coldest northlands might freeze and break grounded Threads. However, the problem is to bring such to the Threads where they fall since they will not oblige us by falling where we want them . . ." he screwed up his face in a grimace.

F'lar stared at him, surprised. Did the man realize how humorous he was? No, he was speaking with sincere concern. Now the Mastersmith scratched his head, his tough fingers making audible grating sounds along his coarse hair and heat-toughened scalp.

"A nice problem. A nice problem," he mused, undaunted. "I shall give it every attention." He sat down, the heavy bench creaking under his weight.

The Masterfarmer raised his hand tentatively.

"When I became Craftmaster, I recall coming across a reference to the sandworms of Igen. They were once cultivated as a protective . . ."

"Never heard Igen produced anything useful except heat and sand . . ." quipped someone.

"We need every suggestion," F'lar said sharply, trying to identify that heckler. "Please find that reference, Craftmaster. Lord Banger of Igen, find me some of those sandworms!"

Banger, equally surprised that his

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arid Hold had a hidden asset, nodded vigorously.

"Until we have more efficient ways of killing Threads, all Holders must be organized on the ground during attacks, to spot and mark burrows, to set firestone to burn in them. I do not wish any man to be scored but we know how quickly Threads burrow deep and no burrow can be left to multiply. You stand to lose more," and he gestured emphatically at the Holder Lords, "than any others. Guard not just yourselves, for a burrow on one man's border may grow across to his neighbor's. Mobilize every man, woman and child, farm and crafthold. Do it now."

The Council Room was fraught with tension and stunned reflection until Zurg, the Masterweaver, rose to speak.

"My Craft, too, has something to offer . . . which is only fair since we deal with thread each day of our lives . . . in regard to the ancient methods." Zurg's voice was light and dry and his eyes, in their creases of spare, lined flesh, were busy, darting from one face in his audience to another. "In Ruath Hold I once saw upon the wall . . . where the tapestry now resides, who knows? . . ." and he slyly glanced at Meron of Nabol and then Bargen of the High Reaches who had succeeded to Fax's title there. "The work was as old as dragonkind and showed, among other things, a man on foot, carrying upon his back a curious contraption. He held within his hand a rounded, sword-long object from which tongues of flame . . . magnificently woven in the orange-red dyes now lost to us . . . spouted towards the ground. Above, of course, were dragons in close formation, bronzes predominating . . . again we've lost that true dragon-bronze shade. Consequently I remember the work as much for what we now lack as for its subject matter."

"A flamethrower?" the Smith rumbled. "A flamethrower," he repeated with a falling inflection. "A flamethrower," he murmured thoughtfully, his heavy brows drawn into a titanic scowl. "A thrower of what sort of flame? It requires thought." He lowered his head and didn't speak, so engrossed in the required thought that he lost interest in the rest of the discussions.

"Yes, good Zurg, there have been many tricks of every trade lost in recent Turns," F'lar commented sardonically. "If we wish to continue living, such knowledge must be revived . . . fast. I would particularly like to recover the tapestry of which Master Zurg speaks."

F'lar looked significantly at those Hold Lords who had quarreled over Fax's seven Holds after that usurper's death in Ruath Great Hall.

"It may save all of you much loss. I suggest that it appear at Ruatha, at Zurg's or Fandarel's Crafthall. Whichever is most convenient."

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There was some shuffling of feet but no admission of ownership.

"It might then be returned to Fay's son who is now Ruatha's Lord," F'lar added, wryly amused at such magnanimous justice.

Lytol, Ruatha's Warder, snorted softly and glowered round the room. F'lar supposed Lytol to be amused and experienced a fleeting regret for the orphaned Gaxom, reared by such a cheerless, if scrupulously honest, guardian.

"If I may, Lord Weyrleader," Robinton broke in, "we might all benefit, as your maps prove to us, from research in our own records." He smiled suddenly, an unexpectedly embarrassed smile. "I own I find myself in some disgrace for we Harpers have let slip unpopular ballads and skimped on some of the longer Teaching Sagas . . . for lack of listeners and, occasionally, in the interest of preserving our skins."

F'lar stifled a laugh. Robinton was a genius.

"I must see the Ruathan tapestry," Fandarel suddenly boomed out.

"I'm sure it will be in your hands very soon," F'lar assured him with more confidence than he dared feel. "My Lords, there is much to be done. Now that you understand what we all face, I leave it in your hands as leaders in your separate Holds and crafts how best to organize your own people. Craftsmen, turn your best minds to our special problems: review all records which might turn up something to our purpose. Lords Telgar, Crom, Ruatha and Nabol, I shall be with you in three days. Nerat, Keroon and Igen, I am at your disposal to help destroy any burrow on your lands. While we have the Masterminer here, tell him your needs. How stands your craft?"

"Happy to be so busy at our trade, Weyrleader," piped up the Masterminer.

Just then F'lar caught sight of F'nor, hovering about in the shadows of the hallway, trying to catch his eye. The brown rider wore an exultant grin and it was obvious he was bursting with news.

F'lar wondered how they could have returned so swiftly from the southern continent and then he realized that F'nor—again—was tanned. He gave a jerk of his head, indicating that F'nor take himself off to the sleeping quarters and wait.

"Lords and Craftmasters, a dragonet will be at the disposal of each of you for messages and transportation. Now, good morning."

He strode out of the Council Room, up the passageway into the queen's weyr, and parted the still swinging curtains into the sleeping room just as F'nor was pouring himself a cup of wine.

"Success!" F'nor cried as the Weyrleader entered. "Though how you knew to send just thirty-two candidates I'll never understand. I

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thought you were insulting our noble Pridith. But thirty-two eggs she laid in four days. It was all I could do to keep from riding out when the first appeared."

F'lar responded with hearty congratulations, relieved that there would be at least that much benefit from this apparently ill-fated venture. Now, all he had to figure out was how much longer F'nor had stayed south until his frantic visit the night before. For there were no worry lines or strain in F'nor's grinning, well-tanned face.

"No queen egg?" asked F'lar hopefully. With thirty-two in the one experiment, perhaps they could send a second queen back and try again.

F'nor's face lengthened. "No, and I was sure there would be. But there are fourteen bronzes, which outmatches Ramoth there," he added proudly.

"Indeed it does. How goes the Weyr otherwise?"

F'nor frowned, shaking his head against an inner bewilderment. "Kylara's . . . well, she's a problem. Stirs up trouble constantly. T'bor leads a sad time with her and he's so touchy every one keeps a distance from him." F'nor brightened a little. "Young N'ton is shaping up into a fine wingleader and his bronze may outfly T'bor's Orth when Pridith flies to mate the next time. Not that I'd wish Kylara on N'ton . . . or anyone."

"No trouble then with supplies?"

F'nor laughed outright. "If you hadn't made it so plain we must not communicate with you here, we could supply you with fruits and fresh greens that are superior to anything in the north. We eat the way dragonmen should! Really, F'lar, we must consider a supply Weyr down there. Then we shall never have to worry about tithing trains and . . ."

"In good time. Get back now. You know you must keep these visits short."

F'nor grimaced. "Oh, it's not so bad. I'm not here in this time anyway."

"True," F'lar agreed, "but don't mistake the time and come while you're still here."

"Hm-m-m? Oh, yes, that's right. I forget time is creeping for us and speeding for you. Well, I shan't be back again till Pridith lays the second clutch."

With a cheerful good-bye, F'nor strode out of the weyr. F'lar watched him thoughtfully as he slowly retraced his steps to the Council Room. Thirty-two new dragons, fourteen of them bronzes, was no small gain and seemed worth the hazard. Or would the hazard wax greater?

Someone cleared his throat deliberately. F'lar looked up to see Robinton standing in the archway that led to the Council Room.

"Before I can copy and instruct others about those maps, Weyr-

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leader, I must myself understand them completely. I took the liberty of remaining behind."

"You make a good champion, Masterharper."

"You have a noble cause, Weyrleader," and then Robinton's eyes glinted maliciously. "I've been begging the Egg for an opportunity to speak out to so noble an audience."

"A cup of wine first?"

"Benden grapes are the envy of Pern."

"If one has the palate for such a delicate bouquet."

"It is carefully cultivated by the knowledgeable."

F'lar wondered when the man would stop playing with words. He had more on his mind than studying the time charts.

"I have in mind a ballad which, for lack of explanation, I had set aside when I became the Master of my Crafthall," he said judiciously after an appreciative savoring of his wine. "It is an uneasy song, both the tune and the words. One develops, as a Harper must, a certain sensitivity for what will be received and what will be rejected . . . forcefully," and he winced in retrospect. "I found that this ballad unsettled singer as well as audience and retired it from use. Now, like that tapestry, I think it bears rediscovery."

After his death, C'gan's instrument had been hung on the Council Room wall till a new Weyrsinger could be chosen. The guitar was very old, its wood thin. Old C'gan had kept it well-tuned and covered. The Masterharper handled it now with reverence, lightly stroking the strings to hear the tone, raising his eyebrows at the fine voice of the instrument.

He plucked a chord, a dissonance. F'lar wondered if the instrument were out of tune or if the Harper had, by some chance, struck the wrong string. But Robinton repeated the odd dischord, then modulated into a weird minor that was somehow more disturbing than the first notes.

"I told you it was an uneasy song. And I wonder if you know the answers to the questions it asks. For I've turned the puzzle over in my mind many times of late."

Then abruptly he shifted from the spoken to the sung tone.

"Gone away, gone ahead,
Echoes roll unanswered.
Empty, open, dusty, dead,
Why have all the weyrfolk fled?

Where have dragons gone together?
Leaving weyrs to wind and weather?
Setting herdbeasts free of tether?
Gone, our safeguards, gone, but whither?

Have they flown to some new weyr
Where cruel Threads some others fear?
Are they worlds away from here?
Why, oh why, the empty Weyr?"

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The last plaintive chord reverberated.

"Of course, you realize that that song was first recorded in the Craft-annals some four hundred Turns ago," Robinton said lightly, cradling the guitar in both arms. "The Red Star had just passed beyond attack-proximity. The people had ample reason to be stunned and worried over the sudden loss of the populations of five Weyrs. Oh, I imagine at the time they had any one of a number of explanations but none . . . not one explanation . . . is recorded." Robinton paused significantly.

"I have found none recorded either," F'lar replied. "As a matter of fact, I had all the Records brought here from the other Weyrs—in order to compile accurate attack timetables. And those other Weyr Records simply end," F'lar made a chopping gesture with one hand. "In Benden's records, there is no mention of sickness, death, fire, disaster; not one word of explanation for the sudden lapse of the usual intercourse between the Weyrs. Benden's records continue blithely, but only for Benden. There is one entry that pertains to the mass disappearance . . . the initiation of a Pern-wide patrol routing, not just Benden's immediate responsibility. And that is all."

"Strange," Robinton mused. "Once the danger from the Red Star was past, the dragons and riders may have gone *between* to ease the drain on the Holds. But I simply cannot believe that. Our Craft-records do mention that harvests were bad and that there had been several natural catastrophes . . . other than the Threads. Men may be gallant and your breed the most gallant of all, but mass suicide? I simply do not accept that explanation . . . not for dragonmen."

"My thanks," F'lar said with mild irony.

"Don't mention it," Robinton replied graciously.

F'lar chuckled appreciatively. "I see we have been too weyrbound as well as too hidebound."

Robinton drained his cup, and looked at it mournfully until F'lar refilled it.

"Well, your isolation served some purpose, you know, and you handled that uprising of the Lords magnificently. I nearly choked to death laughing," Robinton remarked, grinning broadly. "Stealing their women in the flash of a dragon's breath!" He chuckled again and suddenly sobered, looking F'lar straight in the eye. "Accustomed as I am to hearing what a man does *not* say aloud, I suspect there is much you glossed over in that Council Meeting. You may be sure of my discretion . . . and . . . you may be sure of my wholehearted support and that of my not ineffectual Craft. To be blunt, how may my Harpers aid you?" and he strummed a vigorous marching air.

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"Stir men's pulses with ballads of past glories and success?" The tune, under his flashing fingers, changed abruptly to a stern but determined rhythm. "Strengthen their mental and physical sinews for hardship?"

"If all your harpers could stir men as you yourself do, I should have no worries that five hundred or so additional dragons would not immediately end."

"Oho, then despite your brave words and marked charts, the situation is"—a dissonant twang on the guitar accented his final words—"more desperate than you carefully did not say."

"It may be."

"The flamethrowers old Zurg remembered and Fandarel must reconstruct? Will they tip the scales?"

F'lar regarded this clever man thoughtfully, and made a quick decision.

"Even Igen's sandworms will help but as the world turns and the Red Star nears, the interval between daily attacks shortens and we have only seventy-two new dragons to add to those we had yesterday. One is now dead and several will not fly for several weeks."

"Seventy-two?" Robinton caught him up sharply. "Ramoth hatched but forty and they are still too young to eat firestone."

F'lar outlined F'nor and Lessa's expedition, taking place at that moment. He went on to F'nor's reappearance and warning, as well as the fact that the experiment had been successful in part with the hatching of thirty-two new dragons for Pridith's first clutch.

Robinton caught him up. "How can F'nor already have returned when you haven't heard from Lessa and him that there is a breeding place on the southern continent?"

"Dragons can go *between* times as well as places. They go easily from a when to a *where*."

Robinton's eyes widened as he digested this astonishing news.

"That is how we forestalled the attack on Nerat yesterday morning. We jumped back two hours *between* times to meet the Threads as they fell."

"You can actually jump backwards? How far back?"

"I don't know. Lessa, when I was teaching her to fly Ramoth, inadvertently returned to Ruath Hold, to the dawn twelve Turns ago when Fax's men invaded from the heights. When she returned to the present, I attempted a *between* times jump of some ten Turns. To the dragons it is a simple matter to go *between* times or spaces, but there appears to be a terrific drain on the rider. Yesterday, by the time we returned from Nerat and had to go on to Keroon, I felt as though I had been pounded flat and left to dry for a summer on Igen plain." F'lar shook his head. "We have obviously succeeded in sending Kylara, Pridith and the others ten Turns *between*, because F'nor has already reported to me that he has been there several

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Turns. The drain on humans, however, is becoming more and more marked. However, even seventy-two more mature dragons will be a help."

"Send a rider ahead in time and see if it is sufficient," Robinton suggested helpfully. "Save you a few days worrying."

"I don't know how to get some*when* which has not yet happened. You must give your dragon reference points, you know. How can you refer him to times which have not yet occurred?"

"You've got an imagination. Project it."

"And perhaps lose a dragon when I have none to spare? No, I must continue . . . because obviously I have, judging by F'nor's returns . . . as I decided to start. Which reminds me, I must give orders to start packing. Then I shall go over the time charts with you."

It was just after the noonmeal, which Robinton took with the Weyrleader, before the Masterharper was confident he understood the charts and left to begin their copying.

Across a waste of lonely tossing sea,
Where no dragonwings had lately spread,
Flew a gold and a sturdy brown in spring,
Searching if a land be dead.

As Ramoth and Canth bore Lessa and F'nor up to the Star Stone, they saw the first of the Hold Lords and Craftmasters arriving for the Council.

In order to get back to the southern continent of ten Turns ago, Lessa and F'nor had decided it was easiest to transfer first *between* times to the Weyr of ten Turns back which F'nor remembered. Then they would go *between* places to a seapoint just off the coast of the neglected southern continent which was as close to it as the Records gave any references.

F'nor put Canth in mind of a particular day he remembered ten Turns back and Ramoth picked up the references from the brown's mind. The awesome cold of *between* times took Lessa's breath away and it was with intense relief she caught a glimpse of the normal weyr activity before the dragons took them *between* places to hover over the turgid sea.

Beyond them, smudged purple on this overcast and gloomy day, lurked the southern continent. Lessa felt a new anxiety replace the uncertainty of the temporal displacement. Ramoth beat forward with great sweeps of her wings, making for the distant coast. Canth gallantly tried to maintain a matching speed.

"He's only a brown," Lessa scolded her golden queen.

If he is flying with me, Ramoth replied coolly, *he must stretch his wings a little.*

Lessa grinned, thinking very pri-

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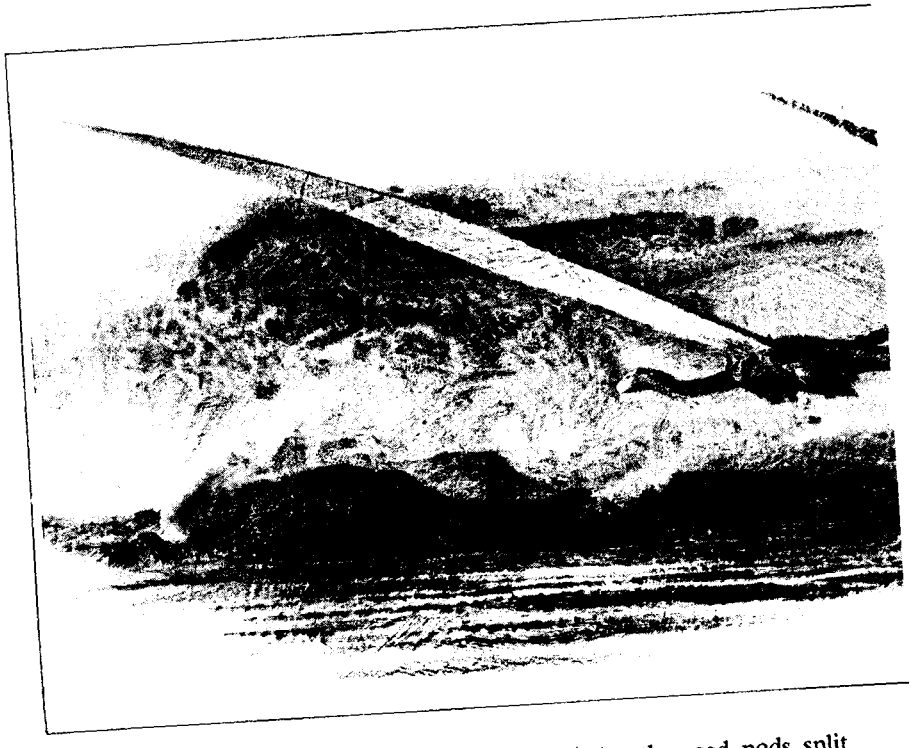

vately that Ramoth was still piqued that she had not been able to fight with her weyrmates. All the males would have a hard time with her for a while.

They saw the flock of wherries first and realized that there would have to be some vegetation on the continent. Wherries needed greens to live although they could subsist on a few grubs if necessary.

Lessa had Canth relay questions to his rider. "If the southern continent were rendered barren by the Threads, how did new growth start? Where did the wherries come from?"

"Ever notice the seed pods split open and the flakes carried away by the winds? Ever notice that wherries fly south after the autumn solstice?"

"Yes, but . . ."

"Yes, but!"

"But the land was thread-bared!"

"In less than four hundred Turns even the scorched hill tops of our continent begin to sprout in the springtime," F'nor replied by way of Canth, "so it is easy to assume the southern continent could revive, too."

Lessa was dubious and berated herself sternly, forcing her mind from F'nor's cryptic warning.

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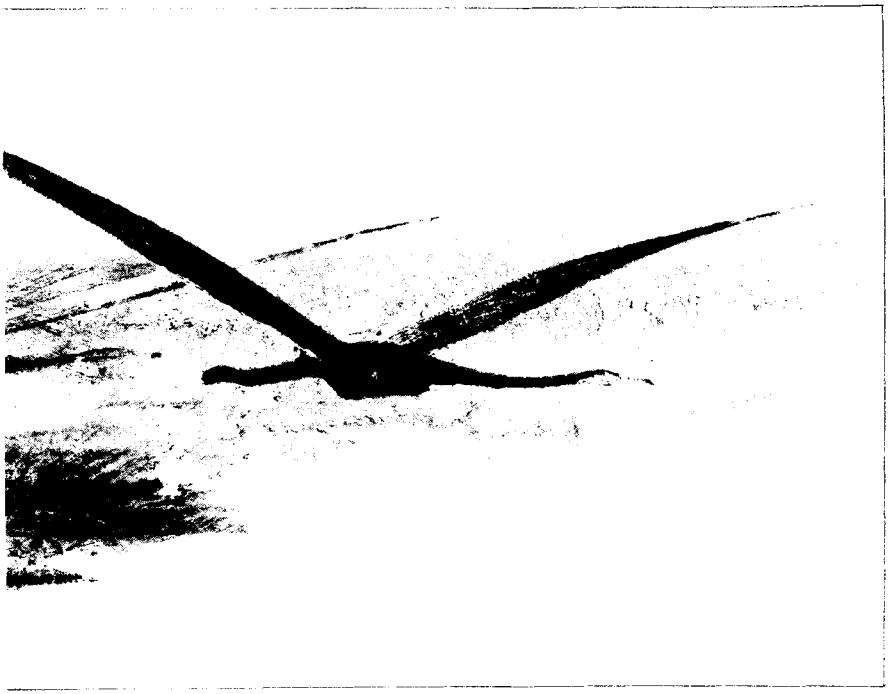

Even at the pace Ramoth set, it took time to reach the jagged shoreline with its forbidding cliffs, stark stone in the sullen light. Lessa groaned inwardly but urged Ramoth higher to see over the masking highlands. All seemed gray and desolate from that altitude.

Suddenly the sun broke through the cloud cover and the gray dissolved into dense greens and browns, living colors, the live greens of lush tropical growth, the browns of vigorous trees and vines. Lessa's cry of triumph was echoed by F'nor's hurrah and the brass voices of the dragons. Wherries, startled by the unusual sound, rose up in alarm from their perches.

Beyond the headland, the land sloped away to jungle and grassy plateau, similar to mid-Boll. Though they searched all morning, they found no hospitable cliffs wherein to found a new Weyr. Was that a contributing factor in the southern venture's failure, Lessa wondered?

Discouraged, they landed on a high plateau by a small lake. The weather was warm but not oppressive and while F'nor and Lessa ate their noonday meal, the two dragons wallowed in the water, refreshing themselves.

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Lessa felt uneasy and had little appetite for the meat and bread. She noticed F'nor was restless, too, shooting surreptitious glances around the lake and the jungle verge.

"What under the sun are we expecting? Wherries don't charge and wild whers would come nowhere near a dragon. We're ten Turns before the Red Star so there can't be any Threads."

F'nor shrugged, grimacing sheepishly as he tossed his unfinished bread back into the food pouch.

"Place just feels so empty, I guess," he tendered, glancing around. He spotted ripe fruit hanging from a moonflower vine. "Now that looks familiar and good enough to eat, without tasting like dust in the mouth."

He climbed nimbly and snagged the orange-red fruit down.

"Smells right, feels ripe, looks ripe," he announced and deftly sliced the fruit open. Grinning, he handed Lessa the first slice, carving another for himself. He lifted it challengingly. "Let us eat and die together!"

She couldn't help but laugh and saluted him back. They bit into the succulent flesh simultaneously. Sweet juices dribbled from the corners of her mouth and Lessa hurriedly licked her lips to capture the least drop of the delicious liquid.

"Die happy, I will," F'nor cried, cutting more fruit.

Both were subtly reassured by the experiment and were able to discuss their discomposure.

"I think," F'nor suggested, "it is the lack of cliff and cavern and the still, still quality of the place; the knowing that there are no other men or beasts about but us."

Lessa nodded her head in agreement. "Ramoth, Canth, would having no weyr upset you?"

We didn't always live in caves, Ramoth replied, somewhat haughtily as she rolled over in the lake. Sizable waves rushed up the shore almost to where Lessa and F'nor were seated on a fallen tree trunk. *The sun here is warm and pleasant, the water cooling. I would enjoy it here but I am not to come.*

"She is out of sorts," Lessa whispered to F'nor. "Let Pridith have it, dear one," she called soothingly to the golden queen, "you've the Weyr and all!"

Ramoth ducked under the water, blowing up a froth in disgruntled reply.

Canth admitted that he had no reservations at all about living weyrless. The dry earth would be warmer than stone to sleep in, once a suitably comfortable hollow had been achieved. No, he couldn't object to the lack of the cave as long as there was enough to eat.

"We'll have to bring herdbeasts in," F'nor mused. "Enough to start a good-sized herd. Of course, the wherries here are huge. Come to think of it, I believe this plateau

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has no exits. We wouldn't need to pasture it off. I'd better check. Otherwise, this plateau with the lake and enough clear space for Holds seems ideal. Walk out and pick breakfast from the tree."

"It might be wise to choose those who were not Hold-reared," Lessa added. "They would not feel so uneasy away from protecting heights and stone-security." She gave a short laugh. "I'm more a creature of habit than I suspected. All these open spaces, untenanted and quiet, seem . . . indecent." She gave a delicate shudder, scanning the broad and open plain beyond the lake.

"Fruitful and lovely," F'nor amended, leaping up to secure more of the orange-red succulents. "This tastes uncommon good to me. Can't remember anything this sweet and juicy from Nerat and yet it's the same variety."

"Undeniably superior to what the Weyr gets. I suspect Nerat serves home first, Weyr last."

They both stuffed themselves greedily.

Further investigation proved that the plateau was isolated, and ample to pasture a huge herd of food beasts for the dragons. It ended in a sheer drop of several dragon-lengths into more dense jungle on one side, the seaside escarpment on the other. The timber stands would provide raw material from which dwellings could be made for the weyrfolk. Ramoth and Canth stoutly agreed dragonkind would be comfortable enough under the heavy foliage of the dense jungle. As this part of the continent was similar, weatherwise, to upper Nerat, there would be neither intense heat nor cold to give distress.

However, Lessa was glad enough to leave. F'nor seemed reluctant to start back.

"We can go *between* time and place on the way back," Lessa insisted finally, "and be in the Weyr by late afternoon. The Lords will surely be gone by then."

F'nor concurred and Lessa steeled herself for the trip *between*. She wondered why the *when between* bothered her more than the *where* for it had no effect on the dragons at all. Ramoth, sensing Lessa's depression, crooned encouragingly. The long, long black suspension of the utter cold of *between* where and when ended suddenly in sunlight above the Weyr.

Somewhat startled, Lessa saw bundles and sacks spread out before the Lower Caverns as dragonriders supervised the loading of their beasts.

"What has been happening?" F'nor exclaimed.

"Oh, F'lar's been anticipating success," she assured him glibly.

Mnementh, who was watching the bustle from the ledge of the queen's weyr, sent a greeting to the travelers and the information that F'lar wished them to join him in the weyr as soon as they returned.

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They found F'lar, as usual, bent over some of the oldest and least legible Record skins which he had had brought to the Council Room.

"And?" he asked, grinning a broad welcome at them.

"Green, lush and livable," Lessa declared, watching him intently. He knew something else, too. Well, she hoped he'd watch his words. F'nor was no fool and this foreknowledge was dangerous.

"That is what I had so hoped to hear you say," F'lar went on smoothly. "Come, tell me in detail. It'll be good to fill in the blank spaces on the chart."

Lessa let F'nor give most of the account to which F'lar listened with sincere attention, making notes.

"On the chance that it would be practical, I started packing supplies and alerting the riders to go with you," he told F'nor when the account was finished. "Remember, we've but three days in this time in which to start you back ten Turns ago. *We* have no moments to spare. And we must have many more mature dragons ready to fight at Telgar in three days time. So, though ten Turns will have passed for you, three days only will elapse here. Lessa, your thought that the farm-bred might do better is well-taken. We're lucky that our recent Search for rider candidates for the dragons Pridith will have came mainly from the crafts and farms. No problem there. And most of the thirty-two are in their early teens."

"Thirty-two?" F'nor exclaimed. "We should have fifty. The dragonets must have some choice even if we get the candidates used to the dragonets before they're hatched."

F'lar shrugged negligently. "Send back for more. *You'll* have time, remember," and F'lar chuckled as though he had started to add something and decided against it.

F'nor had no time to debate with the Weyrleader for F'lar immediately launched on other rapid instructions.

F'nor was to take his own wingriders to help train the weyrlings. They would also take the forty young dragons of Ramoth's first clutch: Kylara with her queen Pridith, T'bor and his bronze Orth. N'ton's young bronze might also be ready to fly and mate by the time Pridith was, so that gave the young queen two bronzes at least.

"Supposing we'd found the continent barren?" F'nor asked, still puzzled by F'lar's assurance. "What then?"

"Oh, we'd've sent them back to say the High Reaches," F'lar replied far too glibly but quickly went on. "I should send on other bronzes but I'll need everyone else here to ride burrow-search on Keroon and Nerat. They've already unearthed several at Nerat. Vincet, I'm told, is close to a heart attack from fright."

Lessa made a short comment on that Hold Lord.

"What of the meeting this morn-

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ing?" F'nor asked, remembering.

"Never mind that now. You've got to start shifting *between* by evening, F'nor."

Lessa gave the Weyrleader a long hard look and decided she'd have to find out what had happened in detail very soon.

"Sketch me some references, will you, Lessa?" F'lar asked.

There was a definite plea in his eyes as he drew clean hide and a stylus to her. He wanted no questions from her now that would alarm F'nor. She sighed and picked up the drawing tool.

She sketched quickly, with one or two details added by F'nor until she had rendered a reasonable map of the plateau they had chosen. Then abruptly, she had trouble focusing her eyes. She felt lightheaded.

"Lessa?" F'lar bent to her.

"Everything's . . . moving . . . circling . . ." and she collapsed backward into his arms.

As F'lar raised her slight body into his arms, he exchanged an alarmed look with his half brother.

"I'll call for Manora," F'nor suggested.

"How do you feel?" the Weyrleader called after his brother.

"Tired but no more than that," F'nor assured him as he shouted down the service shaft to the kitchens for Manora to come and for hot *klah*. He needed that and no doubt of it.

F'lar laid the Weyrwoman on the sleeping couch, covering her gently.

"I don't like this," he muttered, rapidly recalling what F'nor had said of Kylara's decline which F'nor could not know was yet to come in his future. Why should it start so swiftly with Lessa?

"Time-jumping makes one feel slightly . . ." F'nor paused, groping for the exact wording, "not entirely . . . whole. You fought *between* times at Nerat yesterday yourself . . ."

"I fought," F'lar reminded him, "but neither you nor Lessa battled anything today. There may be some inner . . . mental . . . stress simply to going *between* times. Look, F'nor, I'd rather only you came back once you reach the southern weyr. I'll make it an order and get Ramoth to inhibit the dragons. That way no rider can take it into his head to come back even if he wants to. There is some factor which may be more serious than we can guess. Let's take no unnecessary risks."

"Agreed."

"One other detail, F'nor. Be very careful which times you pick to come back to see me. I wouldn't jump *between* too close to any time you were actually here. I can't imagine what would happen if you walked into your own self in the passageway and I can't lose you."

With a rare demonstration of affection, F'lar gripped his half brother's shoulder tightly.

"Remember, F'nor. I was here all morning and you did not arrive back

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from the first trip till mid-afternoon. And remember, too, *we* have only three days. You have ten Turns."

F'nor left, passing Manora in the hall.

The woman could find nothing obviously the matter with Lessa and they finally decided it might be simple fatigue; yesterday's strain when Lessa had to relay messages between dragons and fighters followed by the disjointing *between* times trip today.

When F'lar went to wish the southern venturers a good trip, Lessa was in a normal sleep, her face pale but her breathing easy.

F'lar had Mnementh relay to Ramoth the prohibition he wished the queen to instill in all dragonkind assigned to the venture. Ramoth obliged, but added in an aside to bronze Mnementh, which he passed on to F'lar, that everyone else had adventures while she, the Weyr Queen, was forced to stay behind.

No sooner had the laden dragons,

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one by one, winked out of the sky above the Star Stone, than the young weyrling assigned to Nerat Hold as messenger came gliding down, his face white with fear.

"Weyrleader, many more burrows have been found and they cannot be burned out with fire alone. Lord Vincet wants you."

F'lar could well imagine Vincet did.

"Get yourself some dinner, boy, before you start back. I'll go shortly."

As he passed through to the sleeping quarters, he heard Ramoth rumbling in her throat. She had settled herself down for the night.

Lessa still slept, one hand curled under her cheek, her dark hair trailing over the edge of the bed. She looked fragile, childlike and very precious to him. F'lar smiled to himself. So she was jealous of Kylara's attentions yesterday. He was pleased and flattered. Never would Lessa learn from him that Kylara, for all her bold beauty and sensuous nature, did not have one tenth the attraction for him that the un-

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predictable, dark and delicate Lessa held. Even her stubborn intractableness, her keen and malicious humor, added zest to their relationship. With a tenderness he would never show her awake, F'lar bent and kissed her lips. She stirred and smiled, sighing lightly in her sleep.

Reluctantly returning to what must be done, F'lar left her so. As he paused by the queen, Ramoth raised her great, wedge-shaped head; her many-faceted eyes gleamed with bright luminescence as she regarded the Weyrleader.

"Mnementh, please ask Ramoth to get in touch with the dragonet at Fandarel's Crafthall. I'd like the Mastersmith to come with me to Nerat. I want to see what his agenothree does to Threads."

Ramoth nodded her head as the bronze dragon relayed the message to her.

"She has done so and the green dragon will come as soon as he can," Mnementh reported to his rider. "It is easier to do, this talking about, when Lessa is awake," he grumbled.

F'lar agreed, heartily thankful that Lessa could talk to any dragon in the Weyr. It had been quite an advantage yesterday in the Battle and would be more and more of an asset.

Maybe it would be better if she tried to speak, across time, to F'nor . . . but no, F'nor had come back.

F'lar strode into the Council Room, still hopeful that somewhere within the illegible portions of the old Records was the one clue he so desperately needed. There must be a way out of this impasse. If not the southern venture, then something else. Something!

Fandarel showed himself a man of iron will as well as sinew; he looked calmly at the exposed tangle of perceptibly growing Threads that writhed and intertwined obscenely.

"Hundreds and thousands in this one burrow," Lord Vincet of Nerat was exclaiming in a frantic tone of voice. He waved his hands distractedly around the plantation of young trees in which the burrow had been discovered. "These stalks are already withering even as you hesitate. Do something! How many more young trees will die in this one field alone? How many more burrows escaped dragon's breath yesterday? Where is a dragon to sear them? Why are you just standing there?"

F'lar and Fandarel paid no attention to the man's raving, both fascinated as well as revolted by their first sight of the burrowing stage of their ancient foe. Despite Vincet's panicky accusations, it was the only burrow on this particular slope. F'lar did not like to contemplate how many more might have slipped through the dragons' efforts to reach Nerat's warm and fertile soil. If they had only had time enough to set out watchmen to track the fall of stray clumps . . . they could, at least, remedy that error in Telgar, Crom

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and Ruatha in three days. But it was not enough. Not enough.

Fandarel motioned forward the two craftsmen who had accompanied him. They were burdened with an odd contraption: a large cylinder of metal to which was attached a wand with a wide nozzle. At the other end of the cylinder was another short pipe length and then a short cylinder with an inner plunger. One craftsman worked the plunger vigorously, while the second, barely keeping his hands steady, pointed the nozzle end towards the Thread burrow. At a nod from his pumper, the man released a small knob on the nozzle, extending it carefully away from him and over the burrow. A thin spray danced from the nozzle and drifted down into the burrow. No sooner had the spray motes contacted the Thread tangles than steam hissed out of the burrow. Before long, all that remained of the pallid writhing tendrils was a smoking mass of blackened strands. Long after Fandarel had waved the craftsmen back, he stared at the grave. Finally he grunted and found himself a long stick with which he poked and prodded the remains. Not one Thread wriggled.

"Humph," he grunted with evident satisfaction. "However, we can scarcely go around digging up every burrow. I need another."

With Lord Vincet a hand-wringing moaner in their wake, they were escorted by the junglemen to another undisturbed burrow on the seaside of the rainforest. The Threads had entered the earth by the side of a huge tree which was already drooping.

With his prodding stick, Fandarel made a tiny hole at the top of the burrow and then waved his craftsmen forward. The pumper made vigorous motions at his end while the nozzle-holder adjusted his pipe before inserting it in the hole. Fandarel gave the sign to start and counted slowly before he waved a cutoff. Smoke oozed out of the tiny hole.

After a suitable lapse of time, Fandarel ordered the jungle men to dig, reminding them to be careful not to come in contact with the agenothree liquid. When the burrow was uncovered, the acid had done its work, leaving nothing but a thoroughly charred mass of tangles.

Fandarel grimaced but this time scratched his head in dissatisfaction.

"Takes too much time, either way. Best to get them still at the surface," the Mastersmith grumbled.

"Best to get them in the air," Lord Vincet chattered. "And what will that stuff do to my young orchards? What will it do?"

Fandarel swung round, apparently noticing the distressed Holder for the first time.

"Little man, agenothree in diluted form is what you use to fertilize your plants in the spring. True, this field has been burned out for a few

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years, but it is *not* Thread-full. It *would* be better if we could get the spray up high in the air. Then it would float down and dissipate harmlessly—fertilizing very evenly, too." He paused, scratched his head gratingly. "Young dragons could carry a team aloft. . . . Hm-m-m. A possibility but the apparatus is bulky yet." He turned his back on the surprised Hold Lord then and asked F'lar if the tapestry had been returned. "I cannot yet discover how to make a tube throw flame. I got this mechanism from what we make for the orchard farmers."

"I'm still waiting for word," F'lar replied, "but this spray of yours is effective. The Thread burrow is dead."

"The sandworms are effective too, but not really efficient," Fandarel grunted in dissatisfaction. He beckoned abruptly to his assistants and stalked off into the increasing twilight to the dragons.

Robinton awaited their return at the Weyr, his outward calm barely masking his inner excitement. He inquired politely, however, of Fandarel's efforts. The Mastersmith grunted and shrugged.

"I have all my Craft at work."

"The Mastersmith is entirely too modest," F'lar put in. "He has already put together an ingenious device that sprays agenothree into Thread burrows and sears them into a black pulp."

"Not efficient. *I* like the idea of flamethrowers," the Smith said, his eyes gleaming in his expressionless face. "A thrower of flame," he repeated, his eyes unfocusing. He shook his heavy head with a bone-popping crack. "I go," and with a curt nod to the Harper and the Weyrleader, he left.

"I like that man's dedication to an idea," Robinton observed. Despite his amusement with the man's eccentric behavior, there was a strong undercurrent of respect for the Smith. "I must set my apprentices a task for an appropriate Saga on the Mastersmith. I understand," he said turning to F'lar, "that the southern venture has been inaugurated."

F'lar nodded unhappily.

"Your doubts increase?"

"This *between* times travel takes its own toll," he admitted, glancing anxiously towards the sleeping room.

"The Weyrwoman is ill?"

"Sleeping, but today's journey affected her. We need another, less dangerous answer!" and F'lar slammed one fist into the other palm.

"I came with no real answer," Robinton said then, briskly, "but with what I believe to be another part of the puzzle. I have found an entry. Four hundred turns ago, the then Masterharper was called to Fort Weyr not long after the Red Star retreated away from Pern in the evening sky."

"An entry? What is it?"

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"Mind you, the Thread attacks had just lifted and the Masterharper was called one late evening to Fort Weyr. An unusual summons. However," and Robinton emphasized the distinction by pointing a long, callous-tipped finger at F'lar, "no further mention is ever made of that visit. There ought to have been, for all such summonses have a purpose. All such meetings are recorded yet no explanation of this one is given. The record is taken up several weeks later by the Masterharper as though he had not left this Crafthall at all. Some ten months afterwards, the Question Song was added to compulsory Teaching Ballads."

"You believe the two are connected with the abandonment of the five Weyrs?"

"I do, but I could not say why. I only feel that the events, the visit, the disappearances, the Question Song, are connected."

F'lar poured them both cups of wine.

"I have checked back, too, seeking some indications." He shrugged. "All must have been normal right up to the point they disappeared. There are records of tithe trains received, supplies stored, the list of injured dragons and men returning to active patrols. And then the records cease at full Cold, leaving only Benden Weyr occupied."

"And why that one Weyr of the six to choose from?" Robinton demanded. "Nerat, in the tropics, or island Ista would be better choices if only one Weyr was to be left. Benden so far north is not a likely place to pass four hundred Turns."

"Benden is high and isolated. A disease that struck the others and was prevented from reaching Benden?"

"And no explanation of it? They can't all, dragons, riders, weyrfolk, have dropped dead on the same instant and left no carcasses rotting in the sun."

"Then let us ask ourselves, why was the Harper called? Was he told to construct a Teaching Ballad covering this disappearance?"

"Well," Robinton snorted, "it certainly wasn't meant to reassure us, not with that tune—if one cares to call it a tune at all, and I don't—nor does it answer any questions! It poses them."

"For us to answer?" suggested F'lar softly.

"Aye," and Robinton's eyes shone. "For us to answer, indeed, for it is a difficult song to forget. Which means it was meant to be remembered. Those questions are important, F'lar!"

"Which questions are important?" demanded Lessa who had entered quietly.

Both men were on their feet. F'lar, with unusual attentiveness, held a chair for Lessa and poured her wine.

"I'm not going to break apart," she said tartly, almost annoyed at the excess of courtesy. Then she

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smiled up at F'lar to take the sting out of her words. "I slept and I feel much better. What were you two getting so intense about?"

F'lar quickly outlined what he and the Masterharper had been discussing. When he mentioned the Question Song, Lessa shuddered.

"That's one I can't forget either. Which, I've always been told," and she grimaced, remembering the hateful lessons with R'gul, "means it's important. But why? It only asked questions." Then she blinked, her eyes went wide with amazement.

" 'Gone away, gone . . . *ahead!*' " she cried, on her feet. "That's it! All five Weyrs went . . . *ahead*. But to when?"

F'lar turned to her, speechless.

"They came ahead. To our time, five weyrs full of dragons," she repeated in an awed voice.

"No, that's impossible," F'lar contradicted.

"Why?" Robinton demanded excitedly. "Doesn't that solve the problem we're facing? The need for fighting dragons? Doesn't it explain why they left so suddenly with no explanation except that Question Song?"

F'lar brushed back the heavy lock of hair that overhung his eyes.

"It would explain their actions in leaving," he admitted, "because they couldn't leave any clues saying where they went or it would cancel the whole thing. Just as I couldn't tell F'nor I knew the southern venture would have problems. But how do they get here—if here is *when* they came. They aren't here now. And how, would they have known they were needed—or *when* they were needed? And this is the real problem, how can you conceivably give a dragon references to a *when* that has not yet occurred?"

"Someone here must go back to give them the proper references," Lessa replied in a very quiet voice.

"You're mad, Lessa," F'lar shouted at her, alarm written on his face. "You know what happened to you today. How can you consider going back to a *when* you can't remotely imagine? To a *when* four hundred Turns ago? Going back ten Turns left you fainting and half-ill."

"Wouldn't it be worth it?" she asked him, her eyes grave. "Isn't Pern worth it?"

F'lar grabbed her by the shoulders, shaking her, his eyes wild with fear.

"Not even Pern is worth losing you, or Ramoth. Lessa, Lessa, don't you dare disobey me in this." His voice dropped to an intense, icy whisper, shaking with anger.

"Ah, there may be a way of effecting that solution, momentarily beyond us, Weyrwoman," Robinton put in adroitly. "Who knows what tomorrow holds? It certainly is not something one does without considering every angle."

Lessa did not shrug off F'lar's vise-like grip on her shoulders as she gazed at Robinton.

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"Wine?" The Masterharper suggested, pouring a mug for her. His diversionary action broke the tableau of Lessa and F'lar.

"Ramoth is not afraid to try," Lessa said, her mouth set in a determined line.

F'lar glared at the golden dragon who was regarding the humans, her neck curled round almost to the shoulder joint of her great wing.

"Ramoth is young," F'lar snapped and then caught Mnementh's wry thought even as Lessa did.

She threw her head back, her peal of laughter echoing in the vaulted chamber.

"I'm badly in need of a good joke myself," Robinton remarked pointedly.

"Mnementh told F'lar that he was neither young nor afraid to try either. It was just a long step," Lessa explained, wiping tears from her eyes.

F'lar glanced dourly at the passageway, at the end of which Mnementh lounged on his customary ledge.

A laden dragon comes, the bronze warned those in the weyr. *It is Lytol behind young B'rant on brown Fanth.*

"Now he brings his own bad news?" Lessa asked sourly.

"It is hard enough for Lytol to ride another's dragon or come here at all, Lessa of Ruatha. Do not increase his torment one jot with your childishness," F'lar said sternly.

Lessa dropped her eyes, furious with F'lar for speaking so to her in front of Robinton.

Lytol stumped into the queen's weyr, carrying one end of a large rolled rug. Young B'rant, struggling to uphold the other end, was sweating with the effort. Lytol bowed respectfully towards Ramoth and gestured the young brownrider to help him unroll their burden. As the immense tapestry uncoiled, F'lar could understand why Masterweaver Zurg had remembered it. The colors, ancient though they undoubtedly were, remained vibrant and undimmed. The subject matter was even more interesting.

"Mnementh, send for Fandarel. Here's the model he needs for his flamethrower," F'lar said.

"That tapestry is Ruatha's," Lessa cried indignantly. "I remember it from my childhood. It hung in the Great Hall and was the most cherished of my Bloodline's possessions. Where has it been?" Her eyes were flashing.

"Lady, it is being returned where it belongs," Lytol said stolidly, avoiding her gaze. "A masterweaver's work, this," he went on, touching the heavy fabric with reverent fingers. "Such colors, such patterning. It took a man's life to set up the loom: a craft's whole effort to complete, or I am no judge of true craftsmanship."

F'lar walked along the edge of the immense arras, wishing it could be hung to get the proper perspective

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of the heroic scene. A flying formation of three wings of dragons dominated the upper portion of half the hanging. They were breathing flame as they dove upon gray, falling clumps of Threads in the brilliant sky. A sky, just that perfect autumnal blue, F'lar decided, that cannot occur in warmer weather. Upon the lower slopes of the hills depicted, foliage was turning yellow from chilly nights. The slaty rocks suggested Ruathan country. Was that why the tapestry had hung in Ruatha Hall? Below, men had left the protecting Hold, cut into the cliff itself. The men were burdened with the curious cylinders of which Zurg had spoken. The tubes in their hands belched brilliant tongues of flame in long streams, aimed at the writhing Threads that attempted to burrow in the ground.

Lessa gave a startled exclamation, walking right onto the tapestry, staring down at the woven outline of the Hold, its massive door ajar, the details of its bronze ornamentation painstakingly rendered in fine yarns.

"I believe that's the design on the Ruatha Hold door," F'lar remarked.

"It is . . . and it isn't," Lessa replied in a puzzled voice.

Lytol glowered at her, and then at the woven door. "True. It isn't and yet it is and I went through that door a scant hour ago." He scowled down at the door before his toes.

"Well, here are the designs Fandarel wants to study," F'lar said with relief, as he peered at the flame-throwers.

Whether the Smith could produce a working model from this woven one in time to help them three days hence, F'lar couldn't guess. But if Fandarel could not, no man could.

The Mastersmith was, for him, jubilant over the presence of the tapestry. He lay upon the rug, his nose tickled by the nap as he studied the details. He grumbled, moaned and muttered as he sat cross-legged to sketch and peer.

"Has been done. Can be done. Must be done," he was heard to rumble.

Lessa called for *klah*, bread and meat when she learned from young B'rant that neither he nor Lytol had eaten yet. She served all the men, her manner gay and teasing. F'lar was relieved for Lytol's sake. Lessa even pressed food and *klah* on Fandarel, a tiny figure beside the mammoth man, insisting that he come away from the tapestry and eat and drink. After taking nourishment he could return to his mumbling and drawing.

Fandarel finally decided he had enough sketches and disappeared, to be flown back to his Crafthold.

"No point in asking him when he'll be back. He's too deep in thought to hear," F'lar remarked, amused.

"If you don't mind, I shall excuse myself as well," Lessa said, smiling graciously to the four remaining around the table. "Good Warder Ly-

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tol, young B'rant should soon be excused, too. He's half asleep."

"I most certainly am not, Weyrlady," B'rant assured her hastily, widening his eyes with simulated alertness.

Lessa merely laughed as she retreated into the sleeping chamber. F'lar stared thoughtfully after her.

"I mistrust the Weyrwoman when she uses that particularly docile tone of voice," he said slowly.

"Well, we must all depart . . ." Robinton suggested, rising.

"Ramoth is young but not that foolish," F'lar murmured after the others had left.

Ramoth slept, oblivious of his scrutiny. He reached for the consolation Mnementh could give him, without response. The big bronze was dozing on his ledge.

Black, blacker, blackest
And cold beyond frozen things.
Where is *between* when there is naught
To Life but fragile dragon wings?

"I just want to see that tapestry back on the wall at Ruatha," Lessa insisted to F'lar the next day. "I want it where it belongs."

They had been to check on the injured, and had had one argument already over F'lar's having sent N'ton along with the southern venture. Lessa had wanted him to try riding another's dragon. F'lar had preferred for him to learn to lead a wing of his own in the south, given the years to mature in. He had reminded Lessa, in the hope that it might prove inhibiting to any ideas she had about going four hundred Turns back, about F'nor's return trips and bore down hard on the difficulties she had already experienced.

She had become very thoughtful although she had said nothing.

Therefore, when Fandarel sent word he would like to show F'lar a new mechanism, the Weyrleader felt reasonably safe in allowing Lessa the triumph of returning the purloined tapestry to Ruatha. She went to have the arras rolled and strapped to Ramoth's back.

He watched Ramoth rise with great sweeps of her wide wings, up to the Star Stone before going *between* to Ruatha. R'gul appeared at the ledge, just then, reporting that a huge train of firestone was entering the tunnel. Consequently, busy with such details, it was mid morning before he could get to see Fandarel's crude and not yet effective flamethrower . . . the fire did not "throw" from the nozzle of the tube with any force at all. It was late afternoon before he reached the Weyr again.

R'gul announced sourly that F'nor had been looking for him, twice, in fact.

"Twice?"

"Twice, as I said. He would not leave a message with me for you," and R'gul was clearly insulted by F'nor's refusal.

By the evening meal, when there

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was still no sign of Lessa, F'lar sent to Ruatha to learn that she had indeed brought the tapestry. She had badgered and bothered the entire Hold until the thing was properly hung. For upwards of several hours, she had sat and looked at it, pacing its length occasionally.

She and Ramoth had then taken to the sky above the Great Tower and disappeared. Lytol had assumed, as had everyone at Ruatha, that she had returned to Benden Weyr.

"Mnementh?" F'lar bellowed when the messenger had finished, "Mnementh, where are they?"

Mnementh's answer was a long time in coming.

I cannot hear them, he said finally, his mental voice soft and as full of worry as a dragon's could be.

F'lar gripped the table with both hands, staring at the queen's empty weyr. He knew, in the anguished privacy of his mind, where Lessa had tried to go.

Cold as death, death-bearing,
Stay and die, unguided.
Brave and braving, linger.
This way was twice decided.

Below them was Ruatha's Great Tower. Lessa coaxed Ramoth slightly to the left, ignoring the dragon's acid comments, knowing that she was excited, too.

"That's right, dear, this is exactly the angle at which the tapestry illustrates the Hold door. Only when that tapestry was designed, no one had carved the lintels or capped the door. And there was no Tower, no inner Court, no gate." She stroked the surprisingly soft skin of the curving neck, laughing to hide her own tense nervousness and apprehension at what she was about to attempt.

She told herself there were good reasons prompting her action in this matter. The ballad's opening phrase, "gone away, gone ahead" was clearly a reference to *between* times. And the tapestry gave the required reference points for the jump *between* whens. Oh, how she thanked the masterweaver who had woven that doorway. She must remember to tell him how well he had wrought. She hoped she'd be able to. Enough of that. Of course, she'd be able to. For hadn't the Weyrs disappeared? Knowing they had gone ahead, knowing how to go back to bring them ahead, it was she, obviously, who must go back and lead them. It was very simple and only she and Ramoth could do it. Because they already had.

She laughed again, nervously, and took several deep, shuddering breaths.

"All right, my golden love," she murmured. "You have the reference. You know when I want to go. Take me *between,* Ramoth, *between* four hundred Turns."

The cold was intense, even more penetrating than she had imagined. Yet it was not a physical cold. It was the awareness of the absence of *ev-*

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erything. No light. No sound. No touch. As they hovered, longer and longer, in this nothingness, Lessa recognized the fullblown panic of a kind that threatened to overwhelm her reason. She knew she sat on Ramoth's neck yet she could not feel the great beast under her thighs, under her hands. She tried to cry out inadvertently and opened her mouth to . . . nothing . . . no sound in her own ears. She could not even feel the hands that she knew she had raised to her own cheeks.

I am here, she heard Ramoth say in her mind. *We are together,* and this reassurance was all that kept her from losing her grasp on sanity in that terrifying eon of unpassing, timeless nothingness.

Someone had sense enough to call for Robinton. The Masterharper found F'lar sitting at the table, his face deathly pale, his eyes staring at the empty weyr. The craftmaster's entrance, his calm voice, reached F'lar in his shocked numbness. He sent the others out with a peremptory wave.

"She's gone. She tried to go back four hundred Turns," F'lar said in a tight, hard voice.

The Masterharper sank into the chair opposite the Weyrleader.

"She took the tapestry back to Ruatha." F'lar continued in that same choked voice. "I'd told her about F'nor's returns. I told her how dangerous this was. She didn't argue very much and I know going *between* times had frightened her, if anything could frighten Lessa." He banged the table with an impotent fist. "I should have suspected her. When she thinks she's right, she doesn't stop to analyze, to consider. She just does it!"

"But she's not a foolish woman," Robinton reminded him slowly. "Not even she would jump *between* times without a reference point. Would she?"

" 'Gone away, gone ahead' . . . that's the only clue we have!"

"Now wait a moment," Robinton cautioned him, then snapped his fingers. "Last night, when she walked upon the tapestry, she was uncommonly interested in the Hall door. She discussed it with Lytol."

F'lar was on his feet and halfway down the passageway.

"Come on, man, we've got to get to Ruatha."

Lytol lit every glow in the Hold for F'lar and Robinton to examine the tapestry clearly.

"She spent the afternoon just looking at it," the Warder said, shaking his head. "You're sure she has tried this incredible jump?"

"She must have. Mnementh can't hear either her or Ramoth anywhere. Yet he says he can get an echo from Canth many Turns away and in the southern continent." F'lar stalked past the tapestry. "What is it about the door, Lytol? Think, man!"

"It is much as it is now, save that there are no carved lintels, there is no outer Court, nor Tower . . ."

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"That's it. Oh, by the first Egg, it is so simple. Zurg said this tapestry is old. Lessa must have decided it was four hundred Turns and she has used it as the reference point to go back *between* times."

"Why, then, she's there and safe," Robinton cried, sinking with relief in a chair.

"Oh, no, Harper. It is not as easy as that," F'lar murmured.

Robinton caught his stricken look and the despair echoed in Lytol's face. "What's the matter?"

"There is nothing *between*," F'lar said in a dead voice. "To go *between* places, takes only as much time as for a man to cough three times. *Between* four hundred Turns . . ." his voice trailed off.

Who wills,
Can.
Who tries,
Does.
Who loves,
Lives.

There were voices that first were roars in her aching ears and then hushed beyond the threshold of sound. She gasped as the whirling, nauseating sensation apparently spun her, and the bed which she felt beneath her, round and round. She clung to the sides of the bed as pain jabbed through her head, from somewhere directly in the middle of her skull. She screamed, as much in protest at the pain as from the terrifying, rolling, whirling, dropping, lack of a solid ground.

Yet some frightening necessity kept her trying to gabble out the message she had come to give. Sometimes she felt Ramoth trying to reach her in that vast swooping darkness that enveloped her. She would try to cling to Ramoth's mind, hoping the golden queen could lead her out of this torturing nowhere. Exhausted she would sink down, down, only to be torn from oblivion by the desperate need to communicate.

She was finally aware of a soft, smooth hand upon her arm, of a liquid, warm and savory, in her mouth. She rolled it around her tongue and it trickled down her sore throat. A fit of coughing left her gasping and weak. Then she experimentally opened her eyes and the images before her did not lurch and spin.

"Who . . . are . . . you?" she managed to croak.

"Oh, my dear Lessa . . ."

"Is that who I am?" she asked, confused.

"So your Ramoth tells us," she was assured. "I am Mardra of Fort Weyr."

"Oh, F'lar will be so angry with me," Lessa moaned as her memory came rushing back. "He will shake me and shake me. He always shakes me when I disobey him. But I was right. I was right. Mardra? . . . Oh, that . . . awful . . . nothingness," and she felt herself drifting off into sleep, unable to resist that overwhelming urge. Comfortingly,

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her bed no longer rocked beneath her.

The room, dimly lit by wallglows, was both like her own at Benden Weyr and subtly different. Lessa lay still, trying to isolate that difference. Ah, the Weyr walls were very smooth here. The room was larger, too, the ceiling higher and curving. The furnishings, now that her eyes were used to the dim light and she could distinguish details, were more finely crafted. She stirred restlessly.

"Ah, you're awake again, mystery lady," a man said. Light beyond the parted curtain flooded in from the outer weyr. Lessa sensed rather than saw the presence of others in the room beyond.

A woman passed under the man's arm, moving swiftly to the bedside.

"I remember you. You're Mardra," Lessa said with surprise.

"Indeed I am and here is M'ron, Weyrleader at Fort."

M'ron was tossing more glows into the wallbasket, peering over his shoulder at Lessa to see if the light bothered her.

"Ramoth!" Lessa exclaimed, sitting upright, aware for the first time that it was not Ramoth's mind she touched in the outer weyr.

"Oh, that one," Mardra laughed with amused dismay. "She'll eat us out of the Weyr and even my Loranth has had to call the other queens to restrain her."

"She perches on the Star Stones as if she owned them and keens constantly," M'ron added, less charitably. He cocked an ear. "Ha. She's stopped."

"You can come, can't you?" Lessa blurted out.

"Come? Come where, my dear?" Mardra asked, confused. "You've been going on and on about our 'coming,' and Threads approaching, and the Red Star bracketed in the Eye Rock and . . . my dear, don't you realize, the Red Star has been past Pern these two months?"

"No, no, they've started. That's why I came back *between* times . . ."

"Back? *Between* times?" M'ron exclaimed, striding over to the bed, eyeing Lessa intently.

"Could I have some *klah?* I know I'm not making much sense and I'm not really awake yet. But I'm not mad or still sick and this is rather complicated."

"Yes, it is," M'ron remarked with deceptive mildness. But he did call down the service shaft for *klah*. And he did drag a chair over to her bedside, settling himself to listen to her.

"Of course you're not mad," Mardra soothed her, glaring at her weyrmate. "Or she wouldn't ride a queen."

M'ron had to agree to that. Lessa waited for the *klah* to come, sipping gratefully at its stimulating warmth.

Lessa took a deep breath and began, telling them of the Long Interval between the dangerous passes of the Red Star: How the sole Weyr had fallen into disfavor and con-

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tempt. How Jora had deteriorated and lost control over her queen, Nemorth, so that, as the Red Star neared, there was no sudden increase in the size of clutches. How she had impressed Ramoth to become Benden's Weyrwoman. How F'lar had outwitted the dissenting Hold Lords the day after Ramoth's first mating flight and taken firm command of Weyr and Pern, preparing for the Threads he knew were coming. She told her by now rapt audience of her own first attempts to fly Ramoth and how she had inadvertently gone back *between* times to the day Fax had invaded Ruath Hold.

"Invade . . . my family's Hold?" Mardra had cried, aghast.

"Ruatha has given the Weyrs many famous Weyrwomen," Lessa said with a sly smile at which M'ron burst out laughing.

"She's Ruathan, no question," he assured Mardra.

She told them of the situation in which dragonmen now found themselves, with an insufficient force to meet the Thread attacks. Of the Question Song and the great tapestry.

"A tapestry?" Mardra cried, her hand going to her cheek in alarm. "Describe it to me!"

And when Lessa did, she saw—at last—belief in both their faces.

"My father has just commissioned a tapestry with such a scene. He told me of it the other day because the last battle with the Threads was held over Ruatha." Incredulous, Mardra turned to M'ron who no longer looked amused. "She must have done what she has said she'd done. How could she possibly know about the tapestry?"

"You might also ask your queen dragon, and mine," Lessa suggested.

"My dear, we do not doubt you now," Mardra said sincerely, "but it is a most incredible feat."

"I don't think," Lessa said, "that I would ever try it again, knowing what I do know."

"Yes, this shock makes a forward jump *between* times quite a problem if your F'lar must have an effective fighting force," M'ron remarked.

"You will come? You will?"

"There is a distinct possibility we will," M'ron said gravely and his face broke into a lopsided grin. "You said we left the Weyrs . . . abandoned them, in fact, and left no explanation. We went somewhere . . . somewhen, that is, for we are still here now . . ."

They were all silent for the same alternative occurred to them simultaneously. The Weyrs had been left vacant, but Lessa had no way of proving that the five Weyrs reappeared in her time.

"There must be a way. There must be a way," Lessa cried distractedly. "And there's no time to waste. No time at all!"

M'ron gave a bark of laughter. "There's plenty of time at this end of history, my dear."

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They made her rest, then, more concerned than she was that she had been ill some weeks, deliriously screaming that she was falling, and could not see, could not hear, could not touch. Ramoth, too, they told her, had suffered from the appalling nothingness of a protracted stay *between*, emerging above ancient Ruatha a pale yellow wraith of her former robust self.

The Lord of Ruath Hold, Mardra's father, had been surprised out of his wits by the appearance of a staggering rider and a pallid queen on his stone verge. Naturally and luckily he had sent to his daughter at Fort Weyr for help. Lessa and Ramoth had been transported to the Weyr and the Ruathan Lord kept silence on the matter.

When Lessa was strong enough, M'ron called a Council of Weyrleaders. Curiously, there was no opposition to going . . . provided they could solve the problem of time-shock and find reference points along the way. It did not take Lessa long to comprehend why the dragonriders were so eager to attempt the journey. Most of them had been born during the present Thread incursions. They had now had close to four months of unexciting routine patrols and were bored with monotony. Training Games were pallid substitutes for the real battles they had all fought. The Holds, which once could not do dragonmen favors enough, were beginning to be indifferent. The Weyrleaders could see these incidents increasing as Thread-generated fears receded. It was a morale decay as insidious as a wasting disease in Weyr and Hold. The alternative which Lessa's appeal offered was better than a slow decline in their own time.

Of Benden, only the Weyrleader himself was privy to these meetings. Because Benden was the only Weyr in Lessa's time, it must remain ignorant, and intact, until her time. Nor could any mention be made of Lessa's presence for that, too, was unknown in her Turn.

She insisted that they call in the Masterharper because her Records said he had been called. But, when he asked her to tell him the Question Song, she smiled and demurred.

"You'll write it, or your successor will, when the Weyrs are found to be abandoned," she told him. "But it must be your doing, not my repeating."

"A difficult assignment to know one must write a song that four hundred Turns later gives a valuable clue."

"Only be sure," she cautioned him, "that it is a Teaching tune. It must *not* be forgotten for it poses questions that I have to answer."

As he started to chuckle, she realized she had already given him a pointer.

The discussions—how to go so far safely with no sustained sense deprivations—grew heated. There were more constructive notions, however impractical, on how to find refer-

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ence points along the way. The five Weyrs had not been ahead in time and Lessa, in her one gigantic backward leap, had not stopped for intermediate time marks.

"You did say that a *between* times jump of ten years caused no hardship?" M'ron asked of Lessa as all the Weyrleaders and the Masterharper met to discuss this impasse.

"None. It takes . . . oh, twice as long as a *between* places jump."

"It is the four hundred Turn leap that left you imbalanced, hm-m-m. Maybe twenty or twenty-five Turn segments would be safe enough."

That suggestion found merit until Ista's cautious leader, D'ram, spoke up.

"I don't mean to be a Hold-hider, but there is one possibility we haven't mentioned. How do we know we made the jump *between* to Lessa's time? Going *between* is a chancy business. Men go missing often. And Lessa barely made it here alive."

"A good point, D'ram," M'ron concurred briskly, "but I feel there is more to prove that we do—did—will—go forward. The clues, for one thing; they were aimed at Lessa. The very emergency which left five Weyrs empty that sent her back to appeal for our help . . ."

"Agreed, agreed," D'ram interrupted earnestly, "but what I mean is can you be sure we reached Lessa's time? It hadn't happened yet. Do we know it can?"

M'ron was not the only one who searched his mind for an answer to that. All of a sudden, he slammed both hands, palms down, on the table.

"By the Egg, it's die slow, doing nothing, or die quick, trying. I've had a surfeit of the quiet life we dragonmen must lead after the Red Star passes, till we go *between* in old age. I confess I'm almost sorry to see the Red Star dwindle further from us in the evening sky. I say, grab the risk with both hands and shake it till it's gone. We're dragonmen, aren't we, bred to fight the Threads? Let's go hunting . . . four hundred Turns ahead!"

Lessa's drawn face relaxed. She had recognized the validity of D'ram's alternate possibility and it had touched off bitter fear in her heart. To risk herself was her own responsibility but to risk these hundreds of men and dragons, the weyrfolk who could accompany their men. . . ?

M'ron's ringing words for once and all dispensed with that consideration.

"And I believe," the Masterharper's exultant voice cut through the answering shouts of agreement, "I believe I have your reference points." A smile of surprised wonder illuminated his face. "Twenty Turns or twenty-hundred, you have a guide! And M'ron said it. 'As the Red Star dwindles in the evening sky . . .' "

Later, as they plotted the orbit of

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the Red Star, they found how easy that solution actually was, and chuckled that their ancient foe should be their guide.

Atop Fort Weyr, as on all the Weyrs, were great stones. They were so placed that at certain times of the year they marked the approach and retreat of the Red Star, as it orbited in its erratic, two hundred Turn-long course around their sun. By consulting the Records which, among other morsels of information, included the Red Star's wanderings, it was not hard to plan jumps *between* of twenty-five Turns for each Weyr. It had been decided that the complement of each separate Weyr would jump *between* above its own base, for there would unquestionably be accidents if close to eighteen hundred laden beasts tried it at one point.

Each moment now was one too long away from her own time for Lessa. She had been a month away from F'lar and missed him more than she had thought could be possible. Also, she was worried that Ramoth would mate away from Mnementh. There were, to be sure, bronze dragons and bronze riders eager to do that service, but Lessa had no interest in them.

M'ron and Mardra occupied her with the many details in organizing the exodus so that no clues, past the tapestry and the Question Song which would be composed at a later date, remained in the Weyrs.

It was with a relief close to tears that Lessa urged Ramoth upward in the night sky to take her place near M'ron and Mardra above the Fort Weyr Star Stone. At five other Weyrs, great wings were ranged in formation, ready to depart their own times.

As each Weyrleader's dragon reported to Lessa that all were ready —reference points, determined by the Red Star's travels in mind—it was this traveler from the future who gave the command to jump *between.*

The blackest night must end in dawn,
The sun dispel the dreamer's fear:
When shall my soul's bleak, hopeless pain
Find solace in its darkening weyr?

They had made eleven jumps *between,* the Weyrleaders' bronzes speaking to Lessa as they rested briefly between each jump. Of the eighteen hundred odd travelers, only four failed to come ahead, and they had been older beasts. All five sections agreed to pause for a quick meal and hot *klah,* before the final jump which would be but twelve Turns.

"It is easier," M'ron commented as Mardra served around the *klah,* "to go twenty-five Turns than twelve." He glanced up at the Red Dawn Star, their winking and faithful guide. "It does not alter its position as much. I count on you, Lessa, to give us additional references."

"I want to get us back to Ruatha

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before F'lar discovers I have gone." She shivered as she looked up at the Red Star and sipped hastily at the hot *klah*. "I've seen the Star just like that, once . . . no, twice . . . before at Ruatha." She stared at M'ron, her throat constricting as she remembered that morning: the time she had decided that the Red Star was a menace to her, three days after which Fax and F'lar had appeared at Ruath Hold. Fax had died on F'lar's dagger and she had gone to Benden Weyr. She felt suddenly dizzy, weak, strangely unsettled. She had not felt this way as they paused between other jumps.

"Are you all right, Lessa?" Mardra asked with concern. "You're so white. You're shaking." She put her arm around Lessa, glancing, concerned, at her weyrmate.

"Twelve Turns ago I was at Ruatha," Lessa murmured, grasping Mardra's hand for support. "I was at Ruatha twice. Let's go on quickly. I'm too many in this morning. I must get back. I must get back to F'lar. He'll be so angry."

The note of hysteria in her voice alarmed both Mardra and M'ron. Hastily the latter gave orders for the fires to be extinguished, for the weyrfolk to mount and prepare for the final jump ahead.

Her mind in chaos, Lessa transmitted the references to the other Weyrleaders' dragons: Ruatha in the evening light, the Great Tower, the inner Court, and the land at springtime . . .

A fleck of red in a cold night sky,
A drop of blood to guide them by,
Turn away, Turn away, Turn, be gone,
A Red Star beckons the travelers on.

Between them, Lytol and Robinton forced F'lar to eat, deliberately plying him with wine. At the back of his mind he knew he would have to keep going but the effort was immense, the spirit gone from him. It was no comfort that they still had Pridith and Kylara to continue dragonkind, yet he delayed sending someone back for F'nor, unable to face the reality of that admission: that in sending for Pridith and Kylara, he had acknowledged the fact that Lessa and Ramoth would not return.

Lessa, Lessa, his mind cried endlessly, damning her one moment for her reckless, thoughtless daring; loving her the next for attempting such an incredible feat.

"I said, F'lar, you need sleep now more than wine," Robinton's voice penetrated his preoccupation.

F'lar looked at him, frowning in perplexity. He realized that he was trying to lift the wine jug that Robinton was holding firmly down.

"What did you say?"

"Come. I'll bear you company to Benden. Indeed, nothing could persuade me to leave your side. You have aged years, man, in the course of hours."

"And isn't it understandable. . . ?" F'lar shouted, rising to

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his feet, the impotent anger boiling out of him at the nearest target in the form of Robinton.

Robinton's eyes were full of compassion as he reached for F'lar's arm, gripping it tightly.

"Man, not even this Masterharper has words enough to express the sympathy and honor he has for you. But you must sleep; you have tomorrow to endure and the tomorrow after that you have to fight. The dragonmen must have a leader . . ." and his voice trailed off. "Tomorrow you must send for F'nor . . . and Pridith."

F'lar pivoted on his heel and strode towards the fateful door of Ruatha's great hall.

Oh, Tongue, give sound to joy and sing
Of hope and promise on dragonwing.

Before them loomed Ruatha's Great Tower, the high walls of the Outer Court clearly visible in the fading light.

The klaxon rang violent summons into the air, barely heard over the ear-splitting thunder as hundreds of dragons appeared, ranging in full fighting array wing upon wing, up and down the valley.

A shaft of light stained the flagstones of the Court as the Hold door opened.

Lessa ordered Ramoth down, close to the Tower, and dismounted, running eagerly forward to greet the men who piled out of the door. She made out the stocky figure of Lytol, a handbasket of glows held high above his head. She was so relieved to see him, she forgot her previous antagonism to the Warder.

"You misjudged the last jump by two days, Lessa," he cried as soon as he was near enough for her to hear him over the noise of settling dragons.

"Misjudged? How could I?" she breathed.

M'ron and Mardra came up beside her.

"It is not to worry," Lytol reassured her, gripping her hands tightly in his, his eyes dancing. He was actually smiling at her. "You overshot the day. Go back *between*, return to Ruatha of two days ago. That's all." His grin widened at her confusion. "It is all right," he repeated, patting her hands. "Take this same hour, the Great Court, everything, but visualize F'lar, Robinton and myself here on the flagstones. Place Mnementh on the Great Tower and a blue dragon on the verge. Now go."

Mnementh? Ramoth queried Lessa, eager to see her weyrmate. She ducked her great head and her huge eyes gleamed with scintillating fire.

"I don't understand," Lessa wailed. Mardra slipped a comforting arm around her shoulders.

"But I do, I do, trust me," Lytol pleaded, patting her shoulder awkwardly and glancing at M'ron for support. "It is as F'nor has said.

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You cannot be several places in time without experiencing great distress and when you stopped twelve Turns back, it threw Lessa all to pieces."

"You know that?" M'ron cried.

"Of course. Just go back two days. You see, I *know* you have. I shall, of course, be surprised then, but now, tonight, I know you reappeared two days earlier. Oh, go. Don't argue. F'lar was half out of his mind with worry for you."

"He'll shake me," Lessa cried, like a little girl.

"Lessa!" M'ron took her by the hand and led her back to Ramoth who crouched so her rider could mount.

M'ron took complete charge and had his Fidranth pass the order to return to the references Lytol had given, adding by way of Ramoth a description of the humans and Mnementh.

The cold of *between* restored Lessa to herself although her error had badly jarred her confidence. But then, there was Ruatha again. The dragons happily arranged themselves in tremendous display. And there, silhouetted against the light from the Hall, stood Lytol, Robinton's tall figure and . . . F'lar.

Mnementh's voice gave a brassy welcome and Ramoth could not land Lessa quickly enough to go and twine necks with her mate.

Lessa stood where Ramoth had left her, unable to move. She was aware that Mardra and M'ron were beside her. She was conscious only of F'lar, racing across the Court towards her as fast as he could. Yet she could not move.

He swung her up in his arms, hugging her so tightly she could not doubt the joy of his welcome.

"My darling, my love, how could you gamble so? I have been lost in an endless *between,* fearing for you." He kissed her, hugged her, held her and then kissed her with rough urgency again. Then he suddenly set her on her feet and gripped her shoulders. "Lessa, if you ever . . ." he said, punctuating each word with a flexing of his fingers, and stopped, aware of a grinning circle of strangers surrounding them.

"I told you he'd shake me," Lessa was saying, dashing tears from her face. "But, F'lar, I brought them all . . . all but Benden Weyr. And that is why the five Weyrs were abandoned. I brought them."

F'lar looked around him, looked beyond the leaders to the masses of dragons settling in the Valley, on the heights, everywhere he turned. There were dragons, blue, green, bronze, brown, and a whole wingful of golden queen dragons alone.

"You brought the Weyrs?" he echoed, stunned.

"Yes, this is Mardra and M'ron of Fort Weyr, D'ram and . . ."

He stopped her with a little shake, pulling her to his side so he could see and greet the newcomers.

"I am more grateful than you can

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know," he said and could not go on with all the many words he wanted to add.

M'ron stepped forward, holding out his hand which F'lar seized and held firmly.

"We bring eighteen hundred dragons, seventeen queens, and all that is necessary to implement our Weyrs."

"And they brought flamethrowers, too," Lessa put in excitedly.

"But, to come . . . to attempt it . . ." F'lar murmured in admiring wonder.

M'ron and D'ram and the others laughed.

"Your Lessa showed the way."

". . . With the Red Star to guide us . . ." she said.

"We are dragonmen," M'ron continued solemnly, "as you are yourself, F'lar of Benden. We were told there are Threads here to fight and that's work for dragonmen to do . . . in any time!"

Drummer, beat, and piper, blow,
Harper, strike, and soldier, go.
Free the flame and sear the grasses
'Til the dawning Red Star passes.

Even as the five Weyrs had been settling around Ruatha valley, F'nor had been compelled to bring forward in time his southern weyrfolk. They had all reached the end of endurance in double-time life, gratefully creeping back to quarters they had vacated two days and ten Turns ago.

R'gul, totally unaware of Lessa's backward plunge, greeted F'lar and his Weyrwoman on their return to the Weyr, with the news of F'nor's appearance with seventy-two new dragons and the further word that he doubted any of the riders would be fit to fight.

"Never seen such exhausted men in my life," R'gul rattled on, "can't imagine what could have got into them, with sun and plenty of food and all, and no responsibilities."

F'lar and Lessa exchanged glances.

"Well, the southern Weyr ought to be maintained, R'gul. Think it over."

"I'm a fighting dragonman, not a womanizer," the old dragonrider grunted. "It'd take more than a trip *between* times to reduce me like those others."

"Oh, they'll be themselves again in next to no time," Lessa said and, to R'gul's intense disapproval, she giggled.

"They'll have to be if we're to keep the skies Threadfree," R'gul snapped testily.

"No problem about that now," F'lar assured him easily.

"No problem? With only a hundred and forty-four dragons?"

"Two hundred and sixteen," Lessa corrected him firmly.

Ignoring her, R'gul asked, "Has that smithmaster found a flamethrower that'll work?"

"Indeed he has," F'lar said.

The five Weyrs had indeed brought forward their equipment.

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Fandarel all but snatched examples from their backs and, undoubtedly, every hearth and smithy through the continent would be ready to duplicate the design by morning. M'ron had told F'lar that, in his time, each Hold had ample flamethrowers for every man on the ground. In the course of the Long Interval, however, the throwers must have been either smelted down or lost as incomprehensible devices. D'ram, particularly, was very interested in Fandarel's agenothree sprayer, considering it better than thrown-flame since it would also act as a fertilizer.

"Well," R'gul admitted gloomily, "a flamethrower or two will be some help day after tomorrow."

"We have found something else that will help a lot more," Lessa remarked and then hastily excused herself, dashing into the sleeping quarters.

The sounds which drifted past the curtain were either laughter or sobs and R'gul frowned on both. That girl was just too young to be Weyrwoman at such a time. No stability.

"Has she realized how critical our situation is—even with F'nor's additions—that is, if they can fly?" R'gul demanded testily. "You oughtn't to let her leave the Weyr at all."

F'lar ignored that and began pouring himself a cup of wine.

"You once pointed out to me that the five empty Weyrs of Pern supported your theory that there would be no more Threads."

R'gul cleared his throat, thinking that apologies—even if they might be due the Weyrleader—were scarcely effective against the Threads.

"Now there was merit in that theory," F'lar went on, filling a cup for R'gul. "Not however, as you interpreted it. The five Weyrs were empty because they . . . they came here."

R'gul, his cup halfway to his lips, stared at F'lar. This man also was too young to bear his responsibilities. But . . . he seemed actually to believe what he was saying.

"Believe it or not, R'gul—and in a bare day's time you will—the five Weyrs are empty no longer. They're here, in the Weyrs, in this time. And they shall join us, eighteen hundred strong, tomorrow at Telgar, with flamethrowers and with plenty of battle experience to help us overcome our ancient foe."

R'gul regarded the poor man stolidly for a long moment. Carefully he put his cup down and, turning on his heel, left the weyr. He refused to be an object of ridicule. He'd better plan to take over the leadership tomorrow if they were to fight Threads the day after.

The next morning, when he saw the clutch of great bronze dragons bearing the Weyrleaders and their wingleaders to the conference; R'gul got quietly drunk.

Lessa exchanged good mornings with her friends and then, smiling

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sweetly, left the weyr, saying she must feed Ramoth. F'lar stared after her thoughtfully, then went to greet Robinton and Fandarel who had been asked to attend the meeting, too. Neither Craftmaster said much, but neither missed a word said. Fandarel's great head kept swiveling from speaker to speaker, his deep-set eyes blinking occasionally. Robinton sat with a bemused smile on his face, utterly delighted by the circumstance of ancestral visitors.

F'lar was quickly talked out of resigning his titular position as Weyrleader of Benden on the grounds that he was too inexperienced.

"You did well enough at Nerat and Keroon. Well indeed," M'ron said.

"You call twenty-eight men or dragons out of action good leadership?"

"For a first battle, with every dragonman green as a hatchling? No, man, you were on time at Nerat, however you got there," and M'ron grinned maliciously at F'lar, "which is what a dragonman must do. No, that was well flown, I say. Well flown." The other four Weyrleaders muttered complete agreement with that compliment. "Your Weyr is understrength, though, so we'll lend you enough odd-wing riders till you've got the Weyr up to full strength again. Oh, the queens love these times!" And his grin broadened to indicate that bronze riders did, too.

F'lar returned that smile, thinking that Ramoth was about ready for another mating flight and this time, Lessa . . . Oh, that girl was being too deceptively docile. He'd better watch her closely.

"Now," M'ron was saying, "we left with Fandarel's Crafthold all the flamethrowers we brought up so that the groundmen will be armed tomorrow.

"Aye, and my thanks," Fandarel grunted. "We'll turn out new ones in record time and return yours soon."

"Don't forget to adapt that agenothree for air spraying, too," D'ram put in.

"It is agreed," and M'ron glanced quickly around at the other riders, "that all the Weyrs will meet, full strength, three hours after dawn above Telgar, to follow the Threads' attack across to Crom. By the way, F'lar, those charts of yours that Robinton showed me are superb. We never had them."

"How did you know when the attacks would come?"

M'ron shrugged. "They were coming so regularly even when I was a weyrling, you kind of knew when one was due. But this way is much much better."

"More efficient," Fandarel added approvingly.

"After tomorrow, when all the Weyrs show up at Telgar, we can request what supplies we need to stock the empty Weyrs," M'ron grinned. "Like old times, squeezing extra tithes from the Holders," and he rubbed his hands in anticipation.

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"There's the southern Weyr," F'nor suggested. "We've been gone from there six Turns in this time, and the herdbeasts were left. They'll have multiplied and there'll be all that fruit and grain."

"It would please me to see that southern venture continued," F'lar remarked, nodding encouragingly at F'nor.

"Yes, and continue Kylara down there, please, too," F'nor added urgently, his eyes sparkling with irritation.

They discussed sending for some immediate supplies to help out the newly occupied Weyrs, and then adjourned the meeting.

"It is a trifle unsettling," M'ron said as he shared wine with Robinton, "to find the Weyr you left the day before in good order has become a dusty hulk." He chuckled. "The women of the lower Caverns were a bit upset."

"We cleaned up those kitchens," F'nor replied indignantly. A good night's rest in a fresh time had removed much of his fatigue.

M'ron cleared his throat. "According to Mardra, no man can *clean* anything."

"Do you think you'll be up to riding tomorrow, F'nor?" F'lar asked solicitously. He was keenly aware of the stress of years showing in his half brother's face despite his improvement overnight. Yet those strenuous Turns had been necessary, nor had they become futile even by hindsight with the arrival of eighteen hundred dragons from past time. When F'lar had ordered F'nor ten Turns backward to breed the desperately needed replacements, they had not yet brought to mind the Question Song or known of the Tapestry.

"I wouldn't miss that fight if I were dragonless," F'nor declared stoutly.

"Which reminds me," F'lar remarked, "we'll need Lessa at Telgar tomorrow. She can speak to any dragon, you know," he explained, almost apologetically, to M'ron and D'ram.

"Oh, we know," M'ron assured him. "And Mardra doesn't mind." Seeing F'lar's blank expression, he added, "As senior Weyrwoman, Mardra, of course, leads the queens' wing."

F'lar's face grew blanker. "Queens' wing?"

"Certainly," and M'ron and D'ram exchanged questioning glances at F'lar's surprise. "You don't keep your queens from fighting, do you?"

"Our *queens?* M'ron, we at Benden have had but *one* queen dragon —at a time—for so many generations, that there are those who denounce the legends of queens in battle as black sacrilege!"

M'ron looked rueful. "I had not truly realized how small your numbers were, till this instant." But his enthusiasm overtook him. "Just the same, queens're very useful with

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flamethrowers. They get clumps other riders might miss. They fly in low, under the main wings. That's one reason D'ram's so interested in the agenothree spray. Doesn't singe the hair off the Holders' heads, so to speak, and is far better over tilled fields."

"Do you mean to say that you allow your queens to fly—against Threads?" F'lar ignored the fact that F'nor was grinning, and M'ron, too.

"Allow?" D'ram bellowed. "You can't stop them. Don't you know your Ballads?"

" 'Moreta's Ride'?"

"Exactly."

F'nor laughed aloud at the expression on F'lar's face as he irritably pulled the hanging forelock from his eyes. Then, sheepishly, he began to grin.

"Thanks. That gives me an idea."

He saw his fellow Weyrleaders to their dragons, waved cheerfully to Robinton and Fandarel, more lighthearted than he would have thought he'd be the morning before the second battle. Then he asked Mnementh where Lessa might be.

Bathing, the bronze dragon replied.

F'lar glanced at the empty queen's weyr.

Oh, Ramoth is on the Peak, as usual. Mnementh sounded aggrieved.

F'lar heard the sound of splashing in the bathing room suddenly cease, so he called down for hot *klah*. He was going to enjoy this.

"Oh, did the meeting go well?" Lessa asked sweetly as she emerged from the bathing room, drying-cloth wrapped tightly around her slender figure.

"Extremely. You realize, of course, Lessa, that you'll be needed at Telgar?"

She looked at him intently for a moment before she smiled again.

"I *am* the only Weyrwoman who can speak to any dragon," she replied archly.

"True," F'lar admitted blithely. "And no longer the only queen's rider in Benden . . ."

"I hate you!" Lessa snapped, unable to evade F'lar as he pinned her cloth-swathed body to his.

"Even when I tell you that Fandarel has a flamethrower for you so you can join the queens' wing?"

She stopped squirming in his arms and stared at him, disconcerted that he had outguessed her.

"And that Kylara will be installed as Weyrwoman in the south . . . in this time? As Weyrleader, I need all the peace and quiet I can get between battles . . ."

From the Weyr and from the Bowl
Bronze and brown and blue and
green,
Rise the dragonmen of Pern,
Aloft, on wing; seen, then unseen.

Ranged above the Peak of Benden Weyr, a scant three hours after dawn, two hundred and sixteen dragons held their formations as

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F'lar on bronze Mnementh inspected their ranks.

Below in the Bowl were gathered all the weyrfolk and some of those injured in the first battle. All the weyrfolk, that is, except Lessa and Ramoth. They had gone on to Fort Weyr where the queens' wing was assembling. F'lar could not quite suppress a twinge of concern that she and Ramoth would be fighting, too. A holdover, he knew, from the days when Pern had had but the one queen. If Lessa could jump four hundred Turns *between* and lead five Weyrs back, she could take care of herself and her dragon against Threads.

He checked to be sure that every man was well loaded with firestone sacks, that each dragon was in good color, especially those in from the southern Weyr. Of course, the dragons were fit but the faces of the men still showed evidences of the temporal strains they had endured. He was procrastinating and the Threads would be dropping in the skies of Telgar.

He gave the order to go *between.* They reappeared above, and to the south of Telgar Hold itself, and were not the first arrivals. To the west, to the north and yes, to the east now, wings arrived until the horizon was patterned with the great V's of several thousand dragon wings. Faintly he heard the klaxon bell on Telgar Hold Tower as the unexpected dragon strength was acclaimed from the ground.

"Where is she?" F'lar demanded of Mnementh. "We'll need her presently to relay orders . . ."

She's coming, Mnementh interrupted him.

Right above Telgar Hold another wing appeared. Even at this distance, F'lar could see the difference: the golden dragons shone in the bright morning sunlight.

A hum of approval drifted down the dragon ranks and despite his fleeting worry, F'lar grinned with proud indulgence at the glittering sight.

Just then the eastern wings soared straight upward in the sky as the dragons became instinctively aware of the presence of their ancient foe.

Mnementh raised his head, echoing back the brass thunder of the war cry. He turned his head, even as hundreds of other beasts turned to receive firestone from their riders. Hundreds of great jaws masticated the stone, swallowed it, their digestive acids transforming dry stone into flame producing gases, igniting on contact with oxygen.

Threads! F'lar could see them clearly now against the spring sky. His pulses began to quicken, not with apprehension, but with a savage joy. His heart pounded unevenly. Mnementh demanded more stone and began to speed up the strokes of his wings in the air, gathering himself to leap upward when commanded.

The leading Weyr already belched gouts of orange-red flame into the

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pale-blue sky. Dragons winked in and out, flamed and dove.

The great golden queens sped at cliff-skimming height to cover what might have been missed.

Then F'lar gave the command to gain altitude to meet the Threads halfway in their abortive descent. As Mnementh surged upward, F'lar shook his fist defiantly at the winking Red Eye of the Star.

"One day," he shouted, "we will not sit tamely here, awaiting your fall. We will fall on you, where you spin, and sear you on your own ground."

By the Egg, he told himself, if we can travel four hundred Turns backward, and across seas and lands in the blink of an eye, what is travel from one world to another but a different kind of step?

F'lar grinned to himself. He'd better not mention that audacious notion in Lessa's presence.

Clumps ahead. Mnementh warned him.

As the bronze dragon charged, flaming, F'lar tightened his knees on the massive neck. Mother of us all, he was glad that now, of all times conceivable, he, F'lar, rider of bronze Mnementh, was a Dragonman of Pern! ■

In Times To Come

The February issue of Analog will feature a new Harry Harrison novel, beginning the adventures of one Jason din Alt—you met him before in "Deathworld" and "The Ethical Engineer"—and his Pyrran associates on a world rugged enough to give even Pyrrans a bad time. Pyrrans, you may recall, developed on a 2-G planet that hated them; every life form, plant or animal, on the planet was out to destroy them. The survivors were not delicate.

But whoever named the new planet "Felicity" must have been kidding. It was bleak, barren, constantly wintry, and a 1.5-G world. So the people who were dumped there turned colder, harder, and tougher—and the only hope of taming them to civilization again was to import some even colder, harder, tougher and faster people—Pyrrans.

Makes quite a shindig—and quite a yarn!

And Kelly Freas has done a most excellent portrait of "The Horse Barbarians" of Felicity for the cover.

THE EDITOR

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the reference library

P. Schuyler Miller

JUNIOR DIVISION

If this column should reach you before you do your Christmas shopping, it may help you pick a science-fiction book for that youngster you're trying to persuade that there's more to it than the comics show. This is written in June, with half of the year yet to go and at least one Andre Norton juvenile SF novel promised for late summer, but let's get on with what we have.

Up to this point I have read four books intended for the teen-age set, two for a younger group, and a seventh that pretends to be science fiction but is actually fantasy—rather like a poor man's version of C. S. Lewis's "Perelandra." Some others I have heard of but haven't managed to get hold of.

Two of the four teen-age books stand out. The better of the two is Ted White's "Secret of the Marauder Satellite" (Westminster Press, Philadelphia; 1967; 171 pp.; $3.75). It is the story of a nineteen-year-old Space Cadet assigned to a space station in orbit around the Earth, and to the job of picking up the used-up satellites and other debris still in orbit. He soon finds himself in the midst of a mystery, for a strange satellite, obviously non-human in source, is attacking Earth's satellites and often killing their crews. Not only is this a good story; White has done an outstanding job of creating a real, believable person in his chip-on-shoulder hero—not quite the fashionable antihero of present-day "literature," but prickly and annoying enough to be recognizably human.

Robert Silverberg, in "The Gate of Worlds" (Holt, Rinehart & Winston, New York; 1967; 244 pp.; $4.50), has what is just about the best of what were once the Winston juvenile SF books. He has inverted that fruitful SF stereotype, the alternate world concept, to write an adventure story of a young Englishman seeking his fortune in America in 1963 . . . in a world where the Black Death killed most of the population of Europe in 1348, the Turks advanced unobstructed to the Atlantic, and the Aztec and Inca empires were able to develop without interference. Dan Beauchamp has a knack for making the wrong choice when he reaches a "gate of worlds." We leave him

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about to explore Africa, and I hope we meet him again.

English SF novelist John Christopher has started a juvenile series —his first—with "The White Mountains" (Macmillan, N.Y.; 1967; 184 pp.; $3.95). His heroes are younger; they live in England and France in a future in which Earth has been overrun by the "Tripods"—descendants of Wells' Martians?—who implant electrodes in the brain of every youngster when he or she reaches fourteen, and thereafter brainwash him into tranquil subservience. Three boys try to escape to a supposed haven in Switzerland, beyond the White Mountains where the Tripods never come. Again, the human relations are better worked out and more real than is customary in books for the younger set.

Gerry Turner, a writer I don't know, tells a much more complex though conventional story in "Stranger from the Depths" (Doubleday & Co., Garden City, N.Y.; 1967; 204 pp.; $3.50). Young scuba divers, after a great *tsunami* strikes the New England coast, discover a submarine cave where a scaled humanoid is in suspended animation. He is revived, and they learn that his people inhabited Earth in the Cretaceous of a hundred million years ago, and that they were driven by earth-building catastrophes to build refuges deep inside the crust, getting their power from the heat of the core. But the cities were at war with each other, and predictable hostility and melodrama follow as they seek the buried cities —and find them still peopled. This is on a par with a great deal of the adult science fiction of the 1940s and 1950s, but in comparison with White, Silverberg and Christopher it just doesn't rate.

The non-SF book I mentioned is "Encounter Near Venus," by Leonard Wibberley (Farrar, Straus & Giroux, N.Y.; 1967; 214 pp.; $3.50), who may only be the namesake of the author of the memorable "Mouse That Roared." It's for ages "ten up," is lightly and amusingly written and quite good fun, but blandly disregards science. Three children join their uncle in a flying saucer on a trip to a "planet" which is said to be larger than the Moon and circling Venus at a thousand miles above its surface. This marvelous world, Nede, is peopled by delightful and innocent energy-creatures and by the creatures of Greek myth. It is also under attack by Ka the Smiler, otherwise the Devil.

An English author, Ursula Moray Williams, has a small, pleasant story in "The Moonball" (Meredith Press, N.Y.; 1967; 138 pp.; $3.95), written for ages eight to eleven. A group of English children, during a great storm, find a furry ball with a ravenous appetite that seemingly has arrived from the Moon. The story is the chronicle of their efforts to keep stupid adults

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and scientists from destroying their friend and pet.

Bob Silverberg has tried his hand at science fiction for the younger group in "Planet of Death"—another Holt, Rinehart & Winston book (125 pp.; $2.95) that is as big a failure as "Gate of Worlds" is a success. Either of his own accord or by editorial insistence he has written a rather violent story in short simple sentences of the "This is Bob," "This is Betty," "Bob sees Betty" variety. The plot and characters—a roughneck bounty hunter exiled to a viciously hostile world after being framed for murder—belong in a fairly mature teen-age book or an adult novel; the style simply jars. This author normally does so much better with one hand tied behind him that he must have been wrapped like a mummy when he did this.

THE BEST FROM FANTASY AND SCIENCE FICTION: 16th Series

Edited by Edward L. Ferman • Doubleday & Co., New York • 1967 • 264 pp. • $4.50

This year's collection from *F&SF* has less fantasy than usual. The thirteen stories are rounded out with six Gahan Wilson cartoons and four slight poems.

To reverse my usual procedure, we'll dispose of the non-SF first. Joan Patricia Basch's "Matog" is a comedy of demonic errors. John Christopher's "A Few Kindred Spirits" is a wry little yarn of transmigration in the homosexual set. Norman Spinrad's "The Age of Invention" is a burlesque of our and past ages. And "Apology to Inky," by Robert M. Green, Jr., is by far the best of this group, a nostalgic attempt to "go home again" that to a degree succeeds.

"Luana," by Gilbert Thomas, is a borderliner about the fungus spore brought down from space, which a fanatic mycologist nurtured into something fantastic and erotic. Lloyd Biggle's "And Madly Teach" projects our era of the teaching machines and educational TV into a nightmare of future pedagogy. Isaac Asimov's "The Key" is one of the poorer of his stories about his Holmesian reincarnation, Dr. Wendell Urth: this time the cryptic message that tells where to find an extraterrestrial artifact on the Moon.

Mose Mallette's "The Seven Wonders of the Universe" is a broad and bawdy burlesque of both science fiction and some of the sexier paperbacks. Philip K. Dick's "We Can Remember It for You Wholesale," also in the Ace "Best" collection, offers an intricate twist on the theme of synthetic memories as a substitute for a romantic life. "Experiment in Autobiography," by Ron Goulart, is a zany comedy of absurdity which might have been provided with settings by Dali, but Kenneth Bulmer's "The Adjusted" is black irony with a nasty final bite to it. Roger Zelazny, to maintain his tradition of

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unpredictability, has a "straight" story of weather on a distant world in "The Moment of the Storm."

What matters to Zelazny is what is happening to the people of his story, and in the final story, John Shepley's "Three for Carnival," we have a kind of fantastic invocation of the wild carnival spirit that may well be a fantasy of a neurotic mind.

F&SF, of all the American magazines, offers the greatest variety in theme and writing. This annual anthology is a good sampling.

ANALOG 5

Edited by John W. Campbell • Doubleday & Co., Garden City, N.Y. • 1967 •242 pp. • $4.95

It's hard to know how to report these annual anthologies from Analog to the magazine's own readers. If you read the magazine regularly in 1965, you've probably read all nine of the stories it contains. If you're not a collector, you may want to wait for the paperback edition some time next year.

But for your local library, for people who don't yet know Analog, and for yourself if you weren't reading in '65, here is a good cross-section of what it's like, with the bonus of one of John Campbell's most striking editorials—the part of the magazine most readers turn to first. (An article in the latest issue of *Riverside Quarterly*, the excellent critical review of science fiction published by Leland Sapiro of Saskatoon, Saskatchewan, explodes the claims for the infallibility of the Dutch clairvoyants, but that doesn't affect the basic theme of John's article.)

The longest and most characteristically technological of the nine stories is Joe Poyer's realistic "Mission 'Red Clash' " about a U.S. spy plane trying to carry information about a Russian-Chinese clash back to a control ship on the stormy North Atlantic. The most amusing is John Brunner's "Coincidence Day," about the troubles of an extraterrestrial zoo where all activity cycles are coinciding . . . or, if you don't take it too seriously, Gordon Dickson's already classic "Computers Don't Argue," in which an innocent reader tries to return a damaged book to a book club and winds up executed for the kidnapping and murder of Robert Louis Stevenson, thanks to the unarguable infallibility of a series of computers.

James Schmitz's "Balanced Ecology" is another of this author's one-of-a-kind stories, also promptly anthologized: the ecological pattern involving children and monsters on a frontier world. Mack Reynolds' "The Adventure of the Extraterrestrial" is not one of the best Sherlock Holmes pastiches, and Watson in particular rings false—unless he's a son or nephew of the original doctor, impatiently suffering the old fool's fantasies.

The twist-ending story never dies. There's one in the Brunner story, where it adds spice but wasn't neces-

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sary, and there's one that makes the point in Randall Garrett's "Fighting Division," in which Asia and the United States seem to be cooperating to ward off an invasion from space. There's a painfully telegraphed twist in Jonathan Blake MacKenzie's "Overproof," which raises the question, "Must human beings be human?" Patrick Meadows' "Countercommandment" is a kind of capsule version of the recent novel, "Colossus," and not as well done. Finally Winston P. Sanders—a pen name, I'm told—has the short, slight, ordinary and entertaining "Say It With Flowers," another about war in space.

GIANT METEORITES

By E. L. Krinov • Perigon Press, Oxford, London, Edinburgh, New York, Toronto, Paris, Braunschweif • 397 pp. •$15.00• Reviewed by Ralph A. Hall

Giant Meteorites is a historical book preserving eye-witness accounts of two of the greatest meteoritic falls in recorded history: Tunguska and Sikhote-Aline. The book appeals to the reader in two respects: First as a science adventure, and second as a record of scientific evidence. The book should be of particular interest to cosmologists in general and meteoriticists and astronomers especially, for Tunguska may have been a collision with a small comet head.

There is little point in discussing the author's theoretical considerations, or tables of meteoritic craters and crypto-volcanic structures. This is a historical book and these features are properly historically out of date. It is interesting to note that the author discusses two types of craters separated into impact craters, in which the size of the crater is commensurate with the size of the meteorite, and the explosive crater, in which the cohesive forces of materials involved are insignificant with respect to the energies of the impact. In the first type of crater the meteorite remains solid, either remaining whole or fracturing into solid fragments. He jumps from there into the phase where the meteorite and target turns into a gas, thus skipping over an interesting plastic phase in which the main portions of the meteorite become soft molten. This skip is less understandable in view of the fact that the largest craters of Sikhote-Aline are of the plastic type. The fragments of such an impact are characteristically contorted and twisted. Their inner crystalline features are partially erased. He discusses other notable craters of this type, namely, Henbury, and Wabar. The omissions also include a subject index, but these are less important than the inclusions.

Knowledgeable scientists may as well start reading at page 125 at the beginning of the 141-page chapter on Tunguska. This is a true-to-life adventure into one of the most inaccessible regions of frozen

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Russia. The reader is led through the mysteries, misconceptions, repetitions, and boredom of a scientific: What-done-it? Misdirection, flooding rivers, frostbite and starvation are their lot. When they finally locate the area, they are too close to too big a thing to comprehend the pattern. For all their detailed observations and never ending reports of radially uprooted trees they never realized the significance of the fact that the trees directly under the explosion remained standing, though stripped of their branches. They include pictures of it, but do not give it interpretation. Much of their time was consumed spading into frozen circular swamp holes which they mistakenly believed to be impact craters. The reward for all their effort was a rotten stump in the middle of what they thought was a crater floor. No other solid evidence could have been so perverse.

The phenomena of the "light nights" during which a newspaper could be read outside at midnight for several nights following the fall of Tunguska can best be appreciated by plotting the areas of observation on a globe.

All that was ever found of the meteorite were tiny spherules of glass and magnetic material about 0.1 mm. in diameter.

The Sikhote-Aline iron meteorite shower was handled with more dispatch with respect to the time it took the scientists to get to it and the reporting of the incident. In this case some seventy tons of coarsely crystallized nickel iron invaded the atmosphere. An appreciation of air resistance at supersonic speeds (Mach XLV) probably can be better understood when one realizes that the shock of air resistance shattered a solid chunk of nickel iron causing it to fall in fragments. This also gives a better understanding to crater clusters found there and other parts of the Earth, such as Odessa, Texas, and Henbury, Australia.

In comparing the reports of Tunguska and Sikhote-Aline one comes to realize that in tracking down large meteorites, as with anything else: Practice makes perfect!

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brass tacks

Dear Mr. Campbell:

Mr. Malone—Brass Tacks, August 1967—seems to think that I believe in my own nonsense. This is not the case. My "proof" of the nonexistence of John W. Campbell contains two fallacies:

Fallacy 1. A very small probability can be ignored.

In fact, we ignore small probabilities at our peril; however small the probability that an event E will appear on a single trial, we can make the probability that E will appear at least once in n trials as large as we please by choosing a sufficiently large value of n.

Fallacy 2. Probabilistic arguments can be applied retrospectively.

Once an event has happened, it has happened, and—as Mr. Malone rightly points out—the notion of probability no longer applies to it.

I would like to point out, incidentally, that I did not say that only one part in 10^{25} of Mr. Campbell exists; I said that the probability of Mr. Campbell's having come into existence was 1 in 10^{25}, which is by no means the same thing.

J. V. SMART

183 Howlands
Welwyn Garden City
Herts, England

One interesting problem. It is impossible to demonstrate something is improbable. If you demonstrate it, it is not improbable; it is true! This gets sticky when trying to show a child what "not very likely" means.

Dear Mr. Campbell:

I have very recently entered the SF field as a fan. Mainly because I am nineteen years old and was born in Panama. Since my native language is Spanish, I hardly understood a word on the covers of the SF magazines I used to see in the newsstands.

For several years we have had an all-English TV station. It was the first one to ever come to Panama and it was for the sole benefit of the Americans living in the Canal Zone. Years later,

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Panama started in the business of the television. Yet, the Canal Zone TV station remained the best, for it had no commercials and the programs were fresh from the States—mainly because no dubbing was required. One day I tuned in the SCN TV station and got mad simply because I couldn't follow a word of what was going on. So I decided to learn English.

I began to read as crazy and slowly increasing my vocabulary by learning the meaning of a word by correlation. It took me a little over two months in order to read a novel and understand it from beginning to end. They were SF novels, of course. Pronunciation in English is a more complicated matter. But the little English I learned by word-correlation was enough to earn me a scholarship to the States.

I have been in the U.S.A. some five months, yet I feel as if I had been here all my life. I am planning to become a citizen as soon as I can. That's the only way I can obtain a job as a researcher in the aerospace field. Many times I have looked retrospectively at Panama without feeling any apprehension at all. It is my belief that Science has no political barriers. The Laws of Physics and Chemistry apply throughout the entire Universe as a whole. Earth is too small a place wherein exceptions can take place, not to speak about the multitude of arbitrary land divisions that plague our world.

According to Plato's "Republic," a man is being just whenever he applies the skill he has been gifted with. I would add that justice is being done whenever a man is given the opportunity of practicing his skill wherever he can do his best; specially if he has freely and willingly chosen that particular place.

It can be argued that harm is done to the country whose best men leave to practice elsewhere their outstanding abilities. But how an Aerospace engineer apply his knowledge in a society whose agriculture is less than ten per cent mechanized?

Many fine brains are being wasted in less important matters, just because their particular title means nothing to the people of the country of their origin. They are forced by the circumstances. Would you believe that a friend of my family, is working as a janitor in an accounting office even though he has a M.S. in Marine Biology? And that is quite unexplainable since Panama has the two largest Oceans in the world only fifty miles apart! Oh yes, he is saving money in order to return to U.S.A. in order to work, of course!

Had I had the opportunity to come to the States by my own means—which tend to lim.0—I wouldn't have had to compromise to return to my country by accepting a scholarship from the Institute of International Education, in spite of the fact that they are not paying

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a cent for my scholarship. It is Hanover College who is paying the full expenses. The only thing that ties me to the IIE is my chronic lack of funds, and I have made a decision in that respect.

After reading some SF novels, I have developed some ideas that can easily converted into a novel. [Aha! Here comes the BWB! (Beginning-Writer Bug)] I have discovered that I enjoy writing. I would write for the fun of it, no need of being paid. But I don't really mind if you Editors insist on paying for the ideas you publish.

Since I have had a little less than a year in the learning of the English language, you can guess how difficult it will be for me to express my ideas in a extraneous idiom. (As you must have noticed from the context of this letter.)

Being as "shy" as I am, I will need a sign from you in acknowledgment. A go-ahead sign, so that I can start bugging you with my attempts at putting in writing the batch of ideas that are boiling in my mind—before they evaporate away.

I really hope you won't feel upset. After all we both have the foundations of our own lives in common: Our love for Science. (Er, well I think so. Do you?)

ARY R. LA BONTE
Hanover College
Hanover, Indiana 47243

I publish this letter for several reasons. First, because there's been a lot of angry fuss raised about the U.S. "brain drain"—and this gives a very clear explanation of WHY the brains leave their native lands. From the viewpoint of the "brains" —not that of the native land— which is so annoyed that their trained, competent people don't return. Return to—what? Second, Senor La Bonte, if you can do that well in English after only one year— wait another year and you'll be ready to write fiction in English!

Dear Sir:

It seems a shame to put a story by Christopher Anvil in last place in the light of some of his earlier works. I especially wonder if there are any more of the Centran series in the works. I haven't seen one since "The Toughest Opponent" appeared in Analog in August 1962.

Being a Floridian, from right outside Jacksonville, I was very pleased with "Sleeping Planet," by William F. Burkett, which you serialized in May-June 1964. Such a fine story— and a first effort at that—deserves a follow up. Any word on the possibility of that?

I certainly hope that some more "Covers by Bonestell" are in store for Analog. My copy of your January 1967 cover hangs well and draws comments from a lot of people. They find it hard to believe it was a magazine cover.

For the editorial department, it seems to fit into the attitude of the Barbarian vs. Civilized man argu-

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ment that following the recent riots in Newark, New Jersey Black Power leaders demanded indemnification for all damage done *by them to their neighborhoods,* and also demanded the release of those rioters who were arrested by officials in the performance of their duty. "Buy us off and we might not do it again." It sounds like Munich, circa 1938.

ROBERT L. HALL
P.O. Box 903
Gainesville, Florida 32601

The barbarian attitude tends to be "I should be free to do whatever I want, and somebody ought to pay for it!"

Dear Mr. Campbell:

Mack Reynolds is one of the few authors who can turn a story into a history lesson and get away with it. However in this case I must disagree with the lesson that he is trying to teach. I am referring to the story "Computer War" published in the July issue.

On page 104 he asks whether history would have been any different if Alexander the Great had died before attacking Persia or if Napoleon had died in Egypt or if Hitler had died in Munich during his first Putsch. In the guise of one of his character's Musings he asks these questions and answers that history would not have been any different if these men had died at different times than they actually did. He says that even if these Great Leaders had died history would not have been markedly different because the fortunes of these countries were already set. I disagree.

First let us consider Napoleon. He rose out of relative obscurity to become ruler of most of Europe in about a decade. He was one of the greatest generals of his time. General Bernadotte, no mean general himself, said to his marshalls after deserting Napoleon, "When you face the marshalls, attack; when you face Napoleon, retreat." His downfall was due, not so much to military errors, but to the simple fact that like most other great conquerors before him, he bit off more than he could chew.

Mr. Reynolds also states "It was in the cards that feudalistic Austria and the German and Italian states couldn't stand against the new socioeconomic forces." Nationalism and democracy were the two most important forces at work in Europe at the time of Napoleon. He used both of these to his advantage at first, setting himself up as a liberator in the countries he overran, so he could bring the benefits of the French Revolution to them. However these forces also led to his downfall. When he set up the Continental System to block English trade with the Continent, England retaliated with the Orders In Council setting up an English naval blockade on all those ports which refused to trade with England. This quickly led to an intolerable situation in European countries which

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relied on trade with England. If they traded with England they would be subject to reprisals by Napoleon's troops. If they did not allow English ships to enter their ports they would be put under a Naval blockade and slow economic strangulation. Eventually this led to rebellions in many of the states which were under Napoleon's control and these provided the troops with which he was finally defeated. The socioeconomic forces worked for Germany and Austria at this time. It was another half century before these states finally began to undergo the changes into modern and democratic states.

The French armies never would have gotten anywhere against Germany or Prussia if it had not been for the leadership of Napoleon. Zeal is all very well but it isn't going to do any good unless you have a good general to put it to use.

I believe the same thing is true for Hitler. Hitler displayed all the characteristics of a Great Leader and Prophet type individual. He allowed absolutely no opposition to him or his cause which in many ways had characteristics of a religion. Hitler could take control of a crowd and sway them into an almost religious frenzy. It took a man like Hitler to take control of the chaotic political situation in post World War One Germany. Without Hitler the Nazi party would never have been able to take political control of Germany. And without the totalitarian goverment of Hitler they never would have been able to keep control of Germany after the war started to go badly.

On a lighter vein the last few issues of Analog have been very good. The July issue was one of the best that I have seen in some time. The August issue was also good, especially liked the Bonestell cover and the science fact article. Poul Anderson's story was up to his usual high standards but as in his story "Supernova," I got the feeling that it could have been much better if it had been expanded into a two or three part serial.

On a closing note, you state that the science fact article "The Misers" is "the longest one piece fact article we have ever run, over thirty pages." Shame! As editor of Analog you should know your facts better than that. In the November 1961 issue, you published a science article by Hal Clement, "Gravity Insufficient," which ran to a total of thirty-eight pages, six pages longer than "The Misers." Still, I suppose even omnipotent beings such as magazine editors can be permitted their occasional lapses.

Individuals do play an important role in history! Maybe Mr. Reynolds will realize this when we have to face up to Mao & Company.

KEITH SOLTYS
175 Mark Street
Sault Ste Marie, Ontario, Canada

The gentleman's an historian—and he's right on "Gravity Insufficient"!

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GADGETEER vs. SCIENTIST

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And certainly Goodyear, who made the rubber industry possible, was the purest of pure gadgeteer types. His discovery of vulcanization was strictly the gadgeteer's willingness to grab happily at any accident that comes his way. So some of one of his messes fell on the hot stove—and Eureka! he saw he had the answer he'd spent years trying to find.

When the steel industry really got started—with the Bessemer converter—certain men became Ironmasters who controlled the blowing of the Bessemers. They watched the huge tongue of flame, and judged by its color when the iron had been blown down (decarbonized by oxidation) to steel, and signaled for the air blast to be cut off, and the converter dumped.

Later on, scientists and technicians tried to set up photocells and filters and electrical equipment to do the same thing. They achieved it eventually—but if large-scale steelmaking had depended on the development of electronic systems capable of such high-order discrimination, it would have been a long, long time before a railroad reached across the continent!

Yet no scientist could explain how an Ironmaster could tell when the blow-down should be stopped. It could not be done by just anyone; only certain individuals had the talent that training and experience could develop. Didn't matter how long you trained an apprentice if he didn't have the talent necessary.

But that was well back in the last century, when Scientists didn't have the tremendous status they have now; not having such high status, they weren't so hectically defensive.

The situation with respect to Bessemer converter control at that time was precisely the same as the situation with respect to dowsing rods now. Some people could do it; not everyone could be trained to do it. How the doers did the job could not be explained; there was no way to predict, before actual trial, which individuals would be able to learn, and which would never learn. And the ones who could do it, made the industry work.

Sure—now they have photocell systems that control such processes with superhuman accuracy. And now they have Ishihara Color Vision tests that allow distinguishing between those with hyper-acute color sensitivity, and normal people. They aren't used to distinguish trainable Ironmasters now, of course—but Du Pont, American Cyanamid, and other dye and pigment manufacturers and blenders definitely need them! They have Ishihara tests so subtle that a man needs to be able to distinguish some

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ten thousand different color tones to pass the tests.

And there's no use wasting years training a dye chemist if he inherently lacks the color discrimination essential to the job. No matter how much chemistry and technology you teach him, he'll never make a successful dye-chemist; his field must lie in some other type of chemistry.

The essence of the thing is that gadgeteers inevitably precede scientists. A gadgeteer does something that works; at some later time science catches up with the gadgeteer.

Sometimes the gadget is a simple contraption, with an extremely subtle basis that science can't explain for anything from centuries to decades. Sometimes it's simple in appearance, and in fact, so that science can explain it immediately after it's invented.

Marconi's great invention was the workable method of *detecting* radio waves. Hertz had done his laboratory work (and his work was one of the exceedingly rare instances of pure science leading to a workable gadget before the gadgeteers got there) with exceedingly insensitive techniques. The system he used was so insensitive that the maximum detectable range was measured in meters, not thousands of kilometers.

But while Marconi's coherer technique worked at kilometers instead of meters, it was still poor.

Then somebody found that for some unimaginable reason, a chip of silicon carbide, or galena, or any of several other commonly available substances, put in the circuit made far more sensitive and reliable detectors.

It was known among old-time Navy radio operators that if you used *two* cat's-whiskers on a single galena detector-crystal, and fed a local RF signal into one, and the distant signal in the other, the thing seemed to be fantastically sensitive. Of course there was no scientific explanation for this—it was just a bit of Navy operator folklore, and highly unofficial. So it took another thirty to forty years before Bell Labs finally discovered the point-contact transistor. That involves two pointed probes—known in older times as "cat's-whiskers"—contacting a single semiconductor crystal—galena, lead sulphide, is a semiconductor crystal that occurs naturally. A biasing voltage is applied to one point—it can be either radio frequency or DC; normally we use DC unless we're trying to use the unit as a first detector in a superhetrodyne circuit—and the signal is applied to the other.

The two-point galena detector never got anywhere largely because there was no scientific explanation for the thing, so the fact it worked was rigorously denied, the evidence suppressed as nonevidence, and the matter ignored until after a scientific explanation had been developed. Two world wars later, and

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after the development of radar—which forced them to learn how to produce crystal detectors of high sensitivity, since they had no vacuum tubes that would serve at those frequencies—the scientists discovered the two-point contact transistor.

Sometimes the gadgeteer gets his ideas across by making and selling working units for decades before some scientist finally discovers the explanation for what everybody has been happily using for a lifetime.

One of the reasons the medical profession turned thumbs down on Dr. Ivy's krebiozen work was that nobody could explain how and why it worked. It was held that studies of something so vague were improper.

Remarkable attitude, really; nobody yet has been able to understand the mechanism by which aspirin works. All anyone—in fact everyone!—knows is that it *does* work.

The scientist type tends to deny reality when he can, in full honesty, only deny his ability to understand and explain. He tends to say: "There is no possible mechanism;" when the only statement he has an ethical right to make is: "My knowledge is not sufficient to suggest a possible mechanism."

One of the recent examples of a science finally catching up with a gadgeteer concerns studies of the electrical properties of matter.

Back before the turn of the century, Edison and his research gang developed a new, long-life, mechanically sturdy and reliable storage battery, intended for powering electric trains, cars, street cars, et cetera. He and his crew made tens of thousands of experiments; he had a whole laboratory full of first-class gadgeteers, and there were even a few scientists among them.

They came up with what's known as the nickel-iron battery. Any standard text explains it uses iron negative plates, and nickel oxide positives in a potassium hydroxide electrolyte. More complete descriptions mention that the iron plate has a little mercury added. It was found that that worked better. And lithium hydroxide was added to the potassium hydroxide electrolyte, for no known reason, except that tests showed that the battery worked better that way.

Of course many battery types used amalgamated zinc negative plates—the mercury spread on the zinc prevented corrosion of the zinc to some extent, and helped get the zinc to plate back onto the plate when you recharged the cell.

But it was known that iron didn't amalgamate with mercury; mercury was normally shipped in iron bottles, or flasks. So there was no point in putting mercury in with the iron plates.

It was some years before it was finally found that iron *could* be amalgamated—by electroplating

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mercury onto the iron. In the Edison battery, of course, the conditions for plating a thin layer of amalgamation on the iron were fulfilled.

Now iron has a peculiar chemical characteristic called "passivity." Dunk ordinary iron in strong nitric acid—a powerful oxidizing agent—and it reacts violently for a fraction of a second, then simply quits reacting completely. It's "gone passive." Now the iron plate in an Edison battery is subjected to a powerful oxidizing situation when current is drawn from the cell—it's the oxidation of the iron that supplies the energy the battery yields.

That passive condition is strictly a surface phenomenon; an extremely thin film of some tight, clinging oxide forms, and protects the mass of iron, as the thin film of aluminum oxide protects aluminum, and keeps it from corroding away rapidly in water or air. If you amalgamate the metal, the surface has a layer of liquid mercury —and the oxide film can't cling to the liquid surface. Result: No passivity.

In a storage battery—a little mercury makes the iron plate work better!

But the scientific explanation came decades after the gadgeteers put the highly successful and reliable battery on the market.

Then the matter of lithium hydroxide:

In a recent discussion of electrical properties of materials I was interested to learn that pure nickel oxide is an insulator with about ten times the resistivity of glass. As an electrochemical material, that sounds somewhat discouraging.

However, nickel oxide happens to have semiconductor characteristics. Semiconductor materials are characterized by being insulators of high resistivity when pure, but fairly good conductors when the right kind of impurities are added.

The reason for lithium hydroxide in the Edison battery electrolyte emerges. Lithium hydroxide is not a very good electrolyte—adding it to the KOH solution actually increases the internal resistance of the electrolyte. It seems against good sense to replace some of the very-low-resistance KOH with some relatively-high-resistance LiOH.

However—*now* they tell us!—lithium is one of the very effective impurities in nickel oxide. It reduces the resistivity of the semiconductor material by several orders of magnitude!

Do some checking yourself—and notice how many of the major inventions that have built the world's great industries have come not from scientists, but from gadgeteers.

Inventions that have, at the time, been unexplained and unexplainable—simply workable.

Who needs an explanation—if it works? ■ The Editor.

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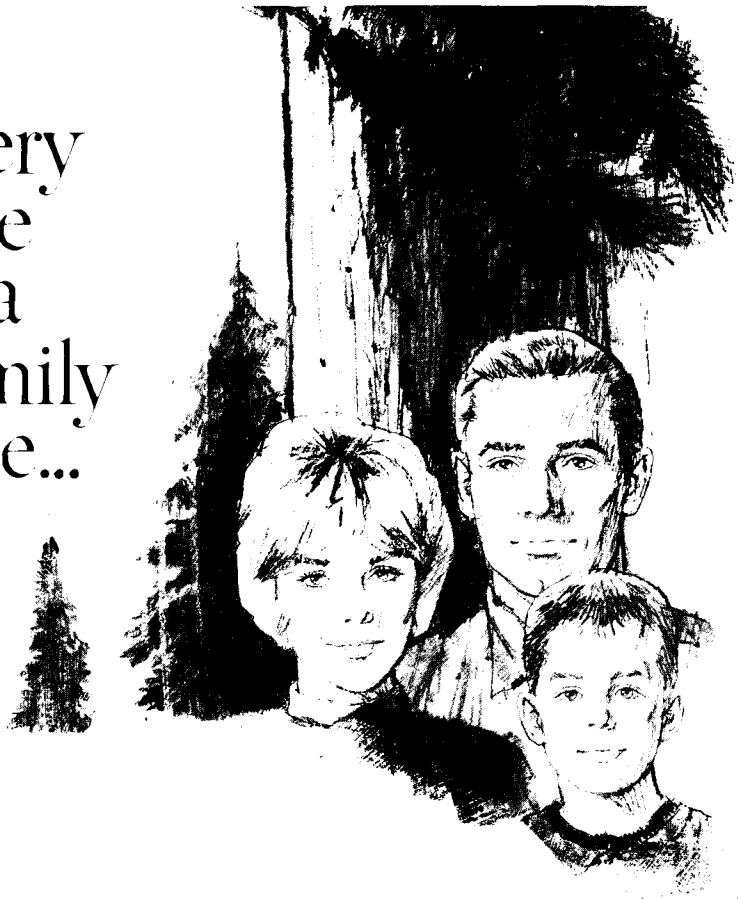

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